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THE ENGINEER CENTENARY NUMBER

On January 4th next we shall publish a special Centenary Number, extra to our normal weekly issues, in celebration of the completion of 100 years of continuous publication of this journal since the first issue appeared on January 4th, 1856. It is our wish that every postal subscriber and regular reader of THE ENGINEER shall receive a free copy of this Number. Postal Subscribers will each be sent one copy of the Number by post.

TO REGULAR READERS WHO BUY THEIR COPIES FROM NEWSAGENTS

Free copies of the Centenary Number are not being distributed through newsagents. Your free copy can only be sent to you if you return to us the reply-paid postcard which was part of an inset facing page 786 of our December 2nd issue.

Please return this postcard now if you have not already done so.

EFFICIENCY AND HUMANITY

The approach of our centenary has inevitably encouraged us to spend several hours lately in looking back over some of our earlier volumes. In no way do we regret the time taken up by that fascinating exercise. It has reminded us, yet again, of the rapidity with which purely technical and scientific developments have occurred over the last hundred years. Our researches have also recalled to us that throughout the last hundred years engineers have been conscious of and anxious about some of those problems which still to-day affect the well-being of the community. As an example, in the years of the last century, as well as in those of the present, this journal has had a good deal to say, one way and another, about such matters as the pollution of the atmosphere and the inadequacy of this country's road system! Those are the sort of problems which certainly prompt us and, we dare believe, many of our readers, to exclaim that "nothing is new under the sun."

Among the newer things which have emerged, however, during the years of our existence there is that which can best be described under the general heading of "industrial welfare." It sprang from something akin to a paternal interest taken by employers in the well-being of their employees; it has now reached the status of a science which contemporary thought holds to be essential to industrial efficiency. In years gone by, there were many examples of employers whose cordial relationships with and benevolence towards their workpeople were seldom proclaimed from the housetops, though they were factors which none the less encouraged efficiency and prosperity. Possibly, these examples were the exception rather than the rule; perhaps the speed of technical development may have tended to turn industry into something nearly approaching the great soulless machine that it has often been labelled. But our attempt to formulate an appraisal of the subject leads us to endorse what has recently been written by Mr. John Marsh, the director of the Industrial Welfare Society. He has suggested that the three main influences leading to improvements in working conditions over the last hundred years have been action by pioneering owners and managers who were stimulated by humanitarian, religious or social movements; statutory legislation prompted by humanitarian movements, and trade unions, which, as defensive alliances of workers, "forced the pace." There is no doubt that all these influences have been strong at different times, and it is likely that, occasionally, the first of them may have been stronger than either of the others. We have discovered, for instance, that in the middle of last century we were regularly exhorting the study of an "illustrated monthly penny paper" entitled *The British Workman and Friend of the Sons of Toil*. This paper, we proclaimed, had "been commenced with an earnest desire of promoting the Health, Wealth and Happiness of the Industrial Classes." At this distance, the whole project savours of a condescending attitude that would now be resented and spurned, but none, surely, could question the good intentions of its promoters. The development of industrial welfare, no matter how or by whom that development was originally inspired, has certainly led to vastly improved working conditions. It has resulted in an industrial environment which has contributed a great deal to efficiency, even though it may not have succeeded in bringing about a state of perfect industrial contentment.

Mr. John Marsh, whose work we have mentioned, has made one other pertinent comment. He has recalled that Seebohm Rowntree pointed out that "welfare is not solely a question of canteens and concerts, but a deeper understanding of human values at work." This is a theme

which Mr. Marsh has ably elaborated in the latest annual report of the Industrial Welfare Society. In that document he remarks upon the attention given to-day to high standards of scientific and technical achievement. But, he goes on to say, " side by side with this, there is a great need for men who have personal qualities and who can influence workers at all levels to be self-respecting, co-operative and efficient." Personal qualities, it is urged, are not only needed among those concerned with management, but also among the specialists, for the " technical specialists of industry can create human problems which sometimes offset the efficiency they set out to achieve." Such comments, we believe, may well suggest an aspect of welfare which industry must keep very much to the fore as it faces the scientific and technical developments of the future. Actual working conditions are, generally, far better now than they have ever been before. Yet even the best working conditions can quickly become ineffectual unless the right kind of human relationship is maintained throughout.

THE LONDON RING AND THE MUNICH STAR

The achievements of the civil engineer only rarely capture the public imagination. Occasionally an unusually vast or imaginative project becomes " news," like the scheme for a high dam at Aswan did quite recently. Or perhaps, more rarely, some crisis in national affairs turns on the work of the civil engineer. The success of the wartime " Mulberry " harbours has become almost legendary, and something of a similar feeling has grown around the hastily constructed sea defences which were built after the storm surge of early 1953. Tragically, no such sentiments have been created about conditions on the roads, where congestion and accidents are so rife, even though the civil engineers' contribution here could be equally spectacular. The Government has announced long-term plans for some road improvements, including one motorway route, but the improvement of traffic flow in large towns remains neglected, except for quite minor adjustments here and there. Even civil engineers themselves sometimes seem to give that problem only a passing interest. At least that was one of the impressions we gained at a recent Institution of Civil Engineers' meeting when the paper " The Planning of Ring Roads with Special Reference to London " by Mr. F. A. Rayfield, was presented and discussed. The meeting was moderately well attended, but other subjects command larger audiences at the Institution's meetings, which is rather paradoxical, for the civil engineer is becoming more and more involved in construction of one sort or another within large cities, and the central core of planning and amenity within a city is to provide efficient and safe circulation of its traffic. The problem is thus fundamental, alike to the civil engineer and the community he serves. Even the paper itself was given, apparently, because the Road Engineering Division happened to have a gap in its programme ; otherwise we might never have heard of this fascinating ring road plan.

The scheme which Mr. Rayfield investigates in his paper is for a motorway route enclosing the central London area, built partly as a viaduct and partly in cutting and tunnel, and with nine access points, as follows : Eaton Square (near Victoria Station), Montague Square (near Marble Arch), Tottenham Court Road, Angel, Aldgate (Gardiners' Corner), Abbey Street, Old Kent Road, Kennington Park Road and Vauxhall Cross. Much of the interest in the paper lies in the detailed investigations of traffic movements and hence of forecasting the volume of traffic which would use the ring, the consequent change in traffic conditions in the roads inside it, and the economic advantages which would result from its use. The paper itself needs to be read for a detailed appraisal of the points ; it also gives a brief, but illuminating history of the various ring road proposals that have been suggested for London. It was pointed out at the meeting that, even now, relatively little basic information is available for the design of the main traffic routes in London and much more work is needed, particularly in origin and destination studies and surveys. In fact surprisingly little serious work has been carried out along such lines, at any rate in most European cities. Whether or not a ring road of this kind would form the basis of the best configuration of main routes across London, was left an open question, alike by the author and subsequent contributors to the discussion. A ring road plan is not necessarily the best one for a city—it could be the worst. The enterprising proposals put forward for the West German city of Munich illustrate this point. An ultimate population of 1,000,000 with 200,000 motor vehicles is envisaged at Munich, with considerable tourist traffic as well. Ring road proposals proved too expensive, but an alternative scheme has been put forward by the city authorities—the so called " Star Line." Munich lies at the centre of a gap between three Bavarian autobahn routes, which could be extended to meet at a " star " junction at the edge of the central part of the city. A site exists where the " star " could be built. The western autobahn would extend radially right to it, but the other two routes would each follow a radial path towards the city, and then turn towards the star, thus forming about half the periphery of a ring route 5km in diameter. This system is considered an ideal skeleton for the main city traffic routes as the western half of the ring is where traffic would be heaviest. A point of particular interest in these proposals is that the projected routes would be built for 14km (mainly the " ring " sections approaching the star) as viaducts, with spans of 25m or more. An official report on the proposals dwells on the " exacting demands of architectural beauty " which modern structures of this kind have to meet, and affirms that the proposed structures will form an integral part of Munich's architectural organism " in perfect harmony with the surrrounding symphony of cultural treasures and scenic beauty."

The situation in London is, of course, rather different. In a vast city, a ring road, such as that described by Mr. Rayfield, might well serve the purpose of the centre of a " star "—a starting point for, and a link between, a radial system of motor roads. That is, perhaps, conjectural, and other schemes have been put forward which do not rely on a ring road. The detailed and practical approach to the ring road scheme, however, immediately commends it. Its value to the community is estimated, conservatively, to be equal to the loan charges which would be incurred by it. But, to quote the paper, " the main point seems to be that if a 50 per cent increase of traffic volume is to be accommodated in the central area of London, the ring road project would enable this to be achieved at less than half the cost of a comparable set of normal surface widenings and intersection improvements." The gross cost of the scheme is estimated at £130 million. By way of comparison, the chairman of London Transport recently stated that the proposed Victoria underground line would cost £50,000,000 to build, and would involve an annual loss of £2,250,000 ; nevertheless its construction was favoured because of the " special and unprecedented problem of London's road congestion." The difficulty in evaluating road schemes is that there is no direct income, except in the case of toll roads. But putting these two schemes—the ring motorway and the underground line—side by side there can surely be little doubt as to which of the two would give better value to the community for money spent. When proposed some years ago, the ring road scheme was not awarded the customary governmental grant and could not go ahead. It may not be the best possible scheme for London, but it is a scheme which appears particularly promising, and which is economically justifiable ; no better scheme has been designed in such detail, to our knowledge. Why then, is it not again seriously put forward by the London County Council for governmental consideration ?

A Seven Day Journal

Investigating Atmospheric Pollution

A REPORT has been published this week, by H.M. Stationery Office, summarising observations made during the ten-year period ended March 31, 1954, concerning the investigation of atmospheric pollution. The work has been carried out under the general direction of the Atmospheric Pollution Research Committee of the Fuel Research Board. The report says that during the last fifteen years there has been a general increase in the pollution in the atmosphere in Great Britain by grit and dust, and small decreases in pollution by smoke and oxides of sulphur. Altogether about 1,500,000 individual measurements were made by local authorities and other co-operating organisations during the ten-year period reviewed. In that period the number of co-operating organisations increased from eighty to 220 and the number of measuring instruments in regular use by them rose from 200 to 1500. The organisation and maintenance of the scheme of measurements, which is the responsibility of the Fuel Research Station, involve supplying many of the instruments, advising on their siting and on other technical aspects of the work. The report shows that in many densely populated industrial areas the amount of pollution may be as much as forty times as great as that in rural areas, and at times of "smog" the average level of pollution by smoke and sulphur may reach ten times the normal for the same time of the year. The report also includes brief descriptions of the investigations by the Fuel Research Station on methods of reducing air pollution. Equipment has been devised for avoiding smoke emission from hand-fired boilers much used in industry, and many boilers have been fitted with it. Other work described relates to the removal of oxides of sulphur from flue gas, production of coke that will give a satisfactory fire even on an old-fashioned fire grate, and research on domestic heating and the testing of domestic heating equipment, one of the objects of which is the more widespread use of stoves and grates that will allow a satisfactory smokeless fire to be maintained with ordinary coke.

British Engineers' Association

MORE than 400 members and guests attended the annual luncheon of the British Engineers' Association, held in London on Wednesday of last week. The chief guest and speaker at the luncheon was Mr. R. A. Butler, the Chancellor of the Exchequer. In introducing Mr. Butler, the president of the Association, Mr. W. Kenneth G. Allen, said that it was in a large measure due to the British engineering industry that the prestige of the capital goods of this country stood so high in the world's markets. The industry was, however, in no way complacent, as it recognised the necessity to maintain the goods it supplied to the highest standards, sell them at competitive prices, and give the best possible deliveries, in order to ensure future prosperity. In reminding the Chancellor that the engineering industry was responsible for some 45 per cent of the country's exports, Mr. Allen asked that the Government should give a greater measure of assistance in overcoming the difficulties in steel supplies, which were still being experienced. In his speech, Mr. Butler said that the two major problems facing industry to-day were shortages of coal and steel, and the question of steel supplies was already being examined by the President of the Board of Trade. He appealed to industrialists to slow down certain investments and cut out less essential projects to reduce demands on men and materials. The Government had no desire to go back to a system of control and allocation, and the present "credit squeeze" was intended to be an effective measure of preventing less essential investment. He said that the country was making too great a demand on its resources and at the same time was not exporting enough to provide a surplus for investment overseas. If the stern internal financial policy recently started was continued it could be expected that the country could get back to the surplus needed to make money available for overseas investments.

Thames-side Firm's Centenary

ON Wednesday of last week, we had the pleasure of attending a luncheon which was held in London to celebrate the centenary of Samuel Williams and Sons, Ltd., of Dagenham Dock, Essex. At this luncheon, the chairman, Mr. A. L. Williams, announced the publication of a book which not only sets out the history of the company, written by Mr. L. T. C. Rolt, but which includes chapters dealing with various aspects of progress in the last hundred years. Thus, Mr. Robert Sinclair has contributed a chapter on "A Century of Change in East London," there is a chapter by Mr. J. Foster Petree entitled "A Century of British Engineering," another by Sir Oscar Hobson on "The Changing Pattern of Enterprise," and, finally, one by Mr. John Marsh on "Industrial Welfare in the Last Hundred Years." Throughout its first century, Samuel Williams and Sons, Ltd., has shown considerable versatility. Its founder was apprenticed to Charles Shutton, a lighterman of St. Mary, Lambeth, "to learn his art, and with him to dwell and serve upon the River of Thames." For many years now the company has owned and operated one of the biggest private docks on the Thames and has been engaged in water, road and rail transport. It is closely associated with the London coal trade, undertakes the distribution of oil fuel, and, in addition, runs a civil engineering contracting business. From its beginning, the company has had its own civil and mechanical engineering departments for the maintenance of its barges, tugs, locomotives, road vehicles and various items of dockside equipment. Those departments, it should be added, have made no small contribution, through the years, to the development and improvement of transport and dockside equipment.

Lloyd's Statistical Tables

LLOYD'S REGISTER OF SHIPPING has issued its "Notes on Statistical Tables, 1955," based on entries to the end of June, which list the principal merchant fleets of the world and compare the totals with 1954. The 1955 world total at 100,569,000 tons represents an increase of 3,147,000 tons, and large increases are shown in Liberia, Norway, Germany, Great Britain, and Northern Ireland and the Netherlands. A total of 19,357,000 gross tons is noted for Great Britain and Northern Ireland, and Liberia, with 3,997,000 tons, has now the fourth largest fleet. Compared with 1939, the outstanding increases are shown as 15,061,000 tons for U.S.A., 3,997,000 tons for Liberia, 3,205,000 tons for Panama, and 2,415,000 tons for Norway, while for Japan and Germany there are decreases of 1,895,000 tons and 1,830,000 tons respectively. A preponderance of ships in the 6000–8000 tons group reflects the wartime building programme, although a large proportion are not in commission. Of ships built during the last five years, the largest group consists of ships within the 10,000–15,000 tons range, and 85 per cent are oil tankers. Similarly, in the next group, that is ships of between 15,000 to 20,000 tons, 85 per cent, excluding ore and oil carriers, are oil tankers. Since 1954 the world tanker fleet has increased by 1,831,000 tons to reach a total of 26,455,000 tons, which represents 26 per cent of all steamships and motorships, as compared with 25 per cent in the previous year. For 1939 the figures were 11,586,000 tons, or 17 per cent. Great Britain and Northern Ireland, with 5,261,000 tons, has the largest oil tanker fleet, followed by the U.S.A. with 4,321,000 tons and Norway with 4,173,000 tons, the next countries in order of size being Liberia and Panama. The tonnage fitted with steam reciprocating engines is 36,984,000 tons, the corresponding figures for turbine machinery and diesel engines being 27,087,000 tons and 34,524,000 tons respectively. The first total represents a reduction of 1,175,000 tons, while the following totals indicate respective increases of 1,669,000 tons and 2,592,000 tons. The tonnage of coal-burning steamships fell by 1,285,000 tons to 9,846,000 tons, and oil-burning steamships increased by 1,840,000 to reach a total of 56,199,000 gross tons. At the end of June last, 10,100 merchant ships of 42,912,000 tons gross were entered in the Register Book to the Society's classification.

The Home of the "Mechanicals"

LAST Friday a special meeting of members of the Institution of Mechanical Engineers was held to consider a resolution authorising the council "to mortgage the leasehold land and premises known as 14, Old Queen Street, Westminster, London, S.W.1." This step is being taken to enable the Institution to complete the acquisition of head leases of property in Old Queen Street, adjoining the "Mechanicals" home as it exists at present. It is interesting to recall that, for the first thirty years of its life, the Institution had its headquarters in Birmingham. The move to London was made in 1877, and early in 1899 the building at Birdcage Walk, Westminster, was occupied. Subsequently, in 1912, the extension in what is now Storey's Gate became possible, and the Institution's home assumed the form that is now so familiar. The membership was then 6160. It is now more than seven times that figure and in recent years it has been necessary for the council to initiate plans designed to secure a major expansion of the property. Three small freehold properties, Nos. 2, 4 and 6, Old Queen Street, were acquired and brought into use as offices in 1949, and in 1952 the Institution acquired the freehold of the site of its main building. In the light of the Institution's continuing expansion, the council decided, some months ago, to obtain, if at all possible, the head leases in the adjoining property in Birdcage Walk and Old Queen Street, which is at present occupied by the Treasury Solicitor. It is realised that this property, in conjunction with the Institution's present building, presents imposing possibilities. The whole project as to the future development of the site, when vacant possession of the recent acquisition can be obtained, is now receiving the council's consideration.

Fuel Control and Burning in Aero-Gas-Turbine Engines

No. I

On Friday, December 16th, the James Clayton Lecture was read by Mr. E. A. Watson, at the Institution of Mechanical Engineers. We abstract below parts of the Lecture dealing with the problem of supplying to the combustion chamber the appropriate amount of fuel at the necessary pressure under all conditions, not only in steady running, but under rapidly varying conditions of acceleration and deceleration.

The Control System

THE aero-gas-turbine engine resembles its piston engine predecessor, in that it has to operate over a wide range of speed (r.p.m.) and inlet pressure, but the operating range is very much wider than for the piston engine. The amount of fuel which is required for steady running is a function of turbine speed and compressor inlet pressure and temperature, and the fuel supply system must be responsive to all these. During acceleration it must supply fuel in excess of the steady running requirements, during deceleration it must supply fuel at a reduced rate, but not low enough to risk flame extinction.

The fuel required for steady running can be expressed mathematically by the relationship

$$F=\frac{kP_1}{\eta_c}\sqrt{T_1}f(N/\sqrt{T_1}) \quad . \quad . \quad . \quad . \quad (1)$$

where F is the fuel required, P_1 is the intake pressure, T_1 is the intake temperature, N is the engine speed, η_c is the combustion efficiency, and k is a constant.

The duty of the fuel system is to translate the solution of this equation into a workable unit.

Since this expression involves four variables it cannot be conveniently expressed in graphical form, but over a wide range of flying conditions the combustion efficiency η_c is substantially unity, and the expression can be written as

$$\frac{F}{P_1}=k\sqrt{T_1}f(N/T_1) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

This is capable of three-dimensional representation as in Fig. 1.

Under normal or so-called I.C.A.N.* conditions T_1 is a function of P_1, the temperature falling as altitude increases until the tropopause is reached at 36.000ft, beyond which it remains constant. When these conditions prevail we can write the expression in a still simpler form as

$$F=F_0\phi(P_1)f(N) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The fuel must therefore be controlled in terms of P_1, the altitude at which the aircraft is operating and N the engine speed at which the pilot wishes to fly.

Normally the engine speed is related to the throttle position θ on the pilot's control, so that in its simplest form the relation becomes

$$F=F_0\theta\phi(P_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Fig. 2 shows the relation between speed and P_1 for a typical case, and indicates the wide range of fuel flow with which the fuel system must deal.

The very wide range in fuel flow required, obviously leads to a very wide range of fuel pressures and, no matter what steps are taken, inevitably leads to a demand for high fuel pressures under full-load conditions.

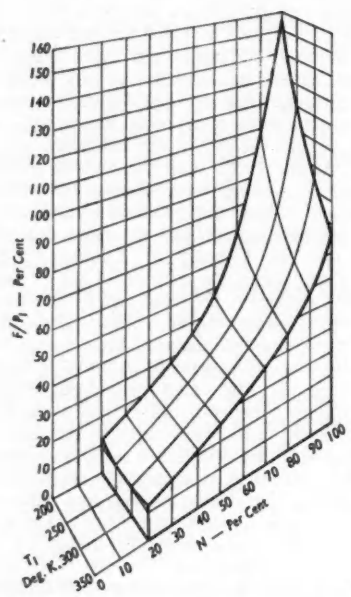


Fig. 1—Specific fuel consumption as function of speed and temperature

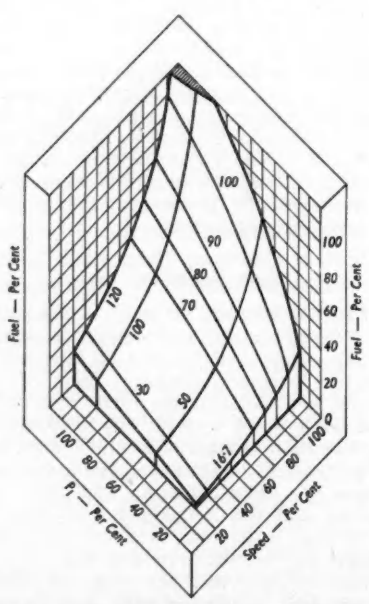


Fig. 2—Relation between fuel speed and intake pressure for a typical gas turbine

Notation.

Block Diagrams.—Large block. A pump of fixed stroke unless otherwise indicated.

Small block marked *C* (control) attached. Indicates that the pump is of variable stroke with a servo control.

O — An orifice. If the orifice is fixed the letter carries no suffix. The addition of a suffix means that the orifice is controlled by the quantity indicated, as follows :—
- O/P_1—Controlled by ambient or intake pressure.
- O/P_2—Controlled by blower pressure.
- $O\theta$—Controlled manually by angular displacement of pilot's lever. This includes, therefore, throttle valves, shut-off cocks, and dump valves.
- OF—Controlled by flow of fluid through orifice.
- O/p_F—Controlled by fluid pressure.
- OL—Controlled electrically by solenoid.

Indicates a sensing means, the balance between two sensed quantities serving to operate the pump servo, such as :
- p/P_1—Ordinary B.P.C. fuel pressure equated to P_1.
- $\Delta p/S$—Pressure drop equated to fixed spring load.
- $\Delta p/\omega S$—Pressure drop equated to variable spring load.
- p_H/S—Hydraulic pressure generated by governor equated to spring loading. (Principle of ordinary hydraulic governor.)

Indicates a transposing device, such as :
- N^2/p_N—Speed to hydraulic pressure. (Hydraulic governor.)
- T/L—Electric temperature control. Electrical system producing current or voltage as a function of T.

LV — The linking valve of a proportional flow control.

* International Commission for Aerial Navigation.

Choice of Parameters

In Britain, practically all aircraft engines employ what is generally termed a scheduling system, the amount of fuel being set to the value appropriate to the throttle setting and altitude with a speed governor override which comes into operation only on maximum throttle opening. American practice, on the other hand, has been to keep the engine under control of a speed governor under all normal flight conditions. The former system is inherently stable and generally simpler, but it does not make allowance for variations in atmospheric temperature or permit of the engine developing the extra thrust of which it is capable at a given speed on a cold day. As can be seen by reference to Fig. 1, the correction for temperature is very large and there is therefore a trend in Britain also, particularly on large and complicated engines, towards the American system using a scheduling system to set the fuel approximately, with a final trim responsive to speed and/or jet pipe temperature.

The types of scheduling system described in my previous paper before the Institution (Watson, 1947)† are still very largely employed but considerable developments are now taking place and a brief review of the position is opportune.

The problem in its simplest form is to supply to the engine a quantity of fuel given by the expression of equation (4); that is, as a function of the relative engine speed or throttle opening θ and a function of the intake pressure P_1. The pressure P_1 is, of course, rather greater than the ambient pressure as a result of the ram effect at the engine intake.

Pressure Control Systems

Fig. 3 shows a block diagram of the simplest way in which this can be carried out. It involves making the fuel line pressure a function of P_1 and interposing a throttle valve in the burner line.

The line pressure may be made a function of P_1 either by using a variable-stroke pump with the stroke controlled by a mechanism actuated by the error signal between fuel line pressure p

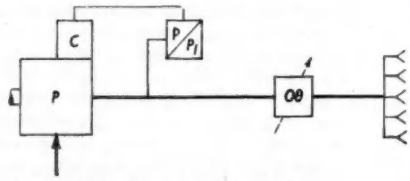


Fig. 3—Block diagram of simple pressure control

and P_1 or by using a fixed-stroke pump with a by-pass valve controlled in the same way. The latter was embodied in the Ricardo barostat, the former in the barometric pressure control (B.P.C.). Both cases have, however, only aimed at approximate solutions. In the former, or B.P.C. unit, shown in Fig. 4, a lever system is employed which balances p, the fuel pressure, directly against P_1, and therefore assumes linearity. In the latter case a limited control of the relation between p and P_1 is possible by using compound springs in the barostat or spill valve unit, which employs an expanding capsule stack as opposed to the fixed length one of the B.P.C. As was shown in the previous paper, the relation between p and P_1 is sufficiently close to a linear one over the altitude range up to about 35,000ft to enable a reasonable compromise to be obtained, and a large number of service and other aircraft are flying in Britain and the continent of Europe with simple controls of this type. In addition, some help can be obtained by using suitable pressurising valves in the fuel line or sprayers following other than the simple quadratic law.

Probably the worst defect of this control is the change in engine speed at an altitude which follows from the fact that the appropriate p/P_1 relation is a function of the throttle opening. This arises from the change in the hydraulic resistance or flow number of the circuit as the

† Watson, E. A., 1948 *Proc. I.Mech.E.*, Vol. 158, page 187.

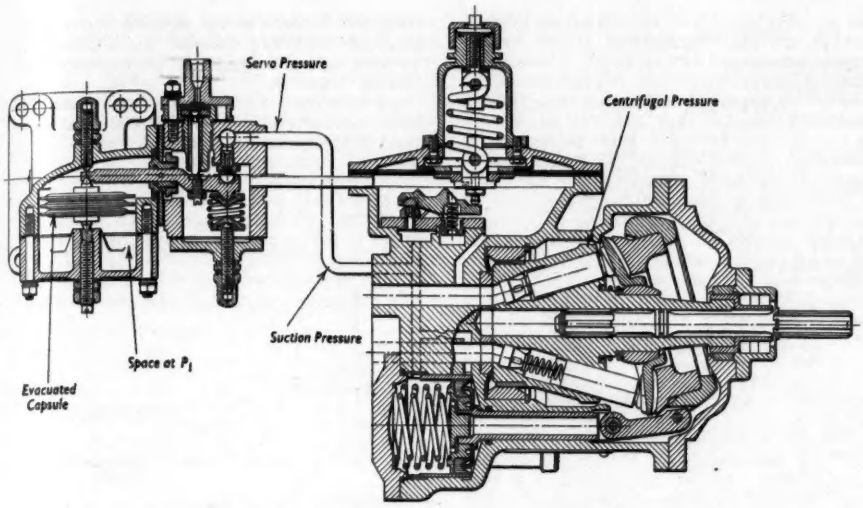


Fig. 4—Elements of pressure-controlled pump and centrifugal-force governor

throttle is closed. The general result is for the idling speed of the engine to rise with altitude and were it not for the fact that this is partly offset by a fall in combustion efficiency and also that some rise in idling speed is desirable for flame stability and quick response on opening up, this defect might be a very serious one.

A method of overcoming it which has been tried experimentally and which is likely to become the basis of certain new control systems is the potentiometer (B.P.C.), shown in block diagram in Fig. 5.

The principle of this is well known to electrical engineers (whence its name) and consists in impressing on the B.P.C. unit a fraction only of the total line pressure, control being obtained by varying the fraction of the pressure which is

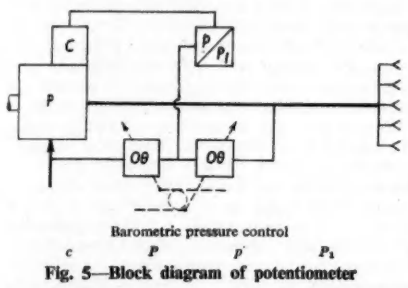


Fig. 5—Block diagram of potentiometer

chosen. Since no throttle valve is employed the flow number of the load circuit does not change with speed and the system therefore eliminates the tendency for speed to rise with altitude.

It will be noted also that the pump duty is reduced, as the maximum fuel pressure is only required under full-speed conditions so that those at cruising are considerably less onerous.

Flow Control Systems

Pressure control systems suffer from the fundamental disadvantage that the metering orifice is in part, at least, formed by the sprayers themselves. Not only does this impose a severe

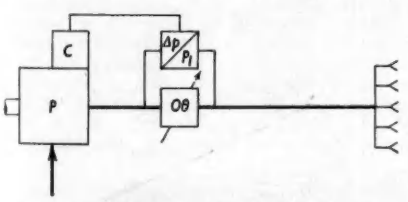


Fig. 6—Block diagram of simple flow control

limitation on sprayer design, but the metering characteristics are also a function of the gas pressure in the combustion chamber which on modern engines may reach high values. Modern practice is therefore to employ a separate metering orifice and use the pressure drop across this as a control parameter. The simplest form of such a control is found in that known generally as the simple flow control. This is shown in block diagram in Fig. 6 and is employed on the "Dart" engines fitted in the "Viscount" aeroplane. It employs an orifice under the control of the pilot and functioning as a throttle valve. The pressure drop across it is equated to P_1 to control the pump servo. As only a moderate pressure drop is employed, this system, like the potentiometer B.P.C., does not involve high pump pressures at small throttle values, but, like the B.P.C. also, it

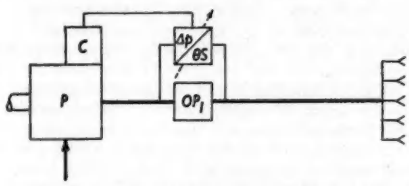


Fig. 7—OP_1 control Ricardo flow barostat

only gives a linear relation between p and P_1 and is therefore suitable only for moderate altitudes. For propeller engines, however, the altitude range suffices to meet present requirements.

An alternative arrangement of a flow control is shown in block form in Fig. 7. Here the metering orifice is made a function of P_1. This, although simple in theory, involves a certain complication in practice, as it is not possible to use a capsule stack to position a metering plunger directly, and a servo system must be employed. Typical arrangements are shown in Fig. 8. The end of the metering plunger is attached to a spring which is attached at its other end to a lever controlling a servo valve and also to a P_1 capsule stack. The servo valve in turn controls the plunger position. Since spring loading and capsule force must be normally in equilibrium, the spring extension and hence plunger position is a unique function of P_1 and, by contouring the plunger the resultant orifice may also be made any desired function of it. The pressure drop Δp across the orifice is equated to a spring force to control the pump output. At any given spring loading any desired relation between fuel flow and P_1 can be obtained.

The throttle parameter can be introduced by making the spring loading S a variable (θS), as indicated in Fig. 7, but this arrangement has the disadvantage that the value of S varies over a wide range. This either means a "woolly"

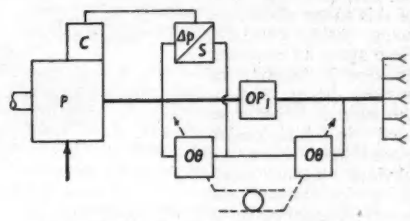


Fig. 9—OP_1 control with potentiometer

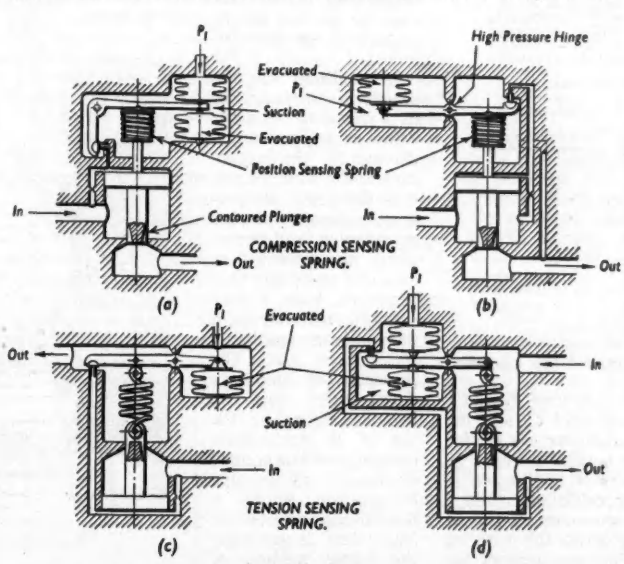
control at one end of the range or inconveniently large forces for the pilot's control mechanism to deal with at the other.

A better arrangement lies in the use of the potentiometric system, as indicated in block form in Fig. 9. Here the control member consists of two small linked throttle valves (or one valve and a fixed orifice) shunting the main orifice. These do not require large operating forces, as no spring loads have to be overcome. (Although shown as two linked valves, they can, of course, be arranged in a common body one opening as the other closes.)

Proportional Flow Control

Flow-control systems have certain inherent disadvantages. One of these is the fact that the metering is carried out by an orifice in the high-pressure line while the pump servo-valve is at a low-pressure level. Hence, any force exerted on a diaphragm or piston subjected to this pressure drop must be transmitted in some way through a wall subject to the fuel pressure which may rise as high as 2000 lb per square inch. Further, whatever transmission means is employed must be as nearly as possible friction-less and devoid of hysteresis. This is a problem which has so far not been completely solved. The flexible wall type of hinge used on the B.P.C. is incapable of standing high-pressure differences, sliding push-rods are liable to trouble through sticking, and the various types of pin hinge which have been used all have to be sealed by some form of rubber seal which may give trouble at low temperatures. The problem is generally intensified by the wide range of forces over which the sensing element has to work and the fact that any friction or sticking must be small compared to the least value of these sensing forces. It becomes more acute when the operating range of speed or altitude is increased. For this reason the type of control where a small push-rod serves to transmit the force through the pressure wall would not be satisfactory on an engine operating over a very wide altitude range although quite satisfactory on the class of service for which it is designed.

Another disadvantage on large engines in particular is the difficulty of providing speed and temperature trims, as if these are carried out by



a—Spill to suction. *b*—Downstream spill. *c*—Downstream spill. *d*—Spill to suction.

Fig. 8—Principles of pressure-controlled metering orifice

supplementary orifices in the main fuel line they entail large orifices which require correspondingly large forces to control them. In order to overcome these drawbacks a system has been developed under the title of a proportional flow control. In this, as the name implies, a certain proportion of the main fuel flow is bled off and used for metering purposes, the ratio of this to the main flow being held constant. Here again an electrical analogy is helpful, the analogy being that of the current transformer used in high-tension power lines where, for obvious reasons, measuring instruments and controls cannot be placed directly in the high-tension line, but are connected to it by means of an instrument transformer which gives a current in the secondary circuit proportional to the line current.

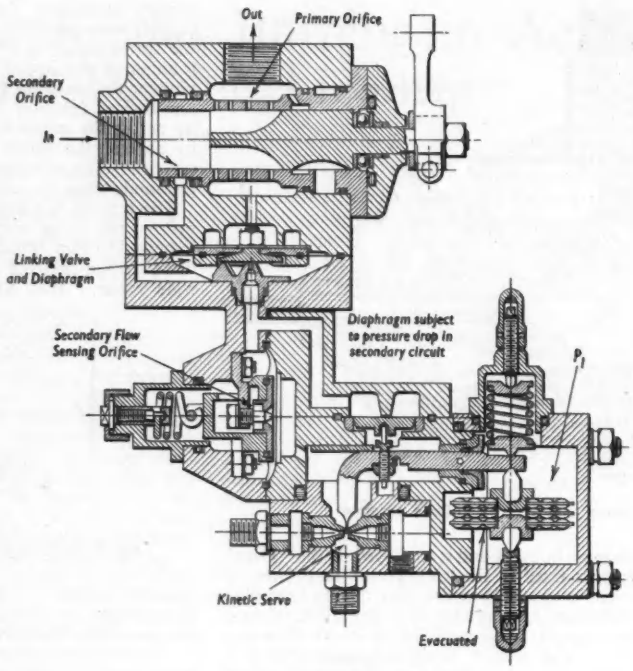
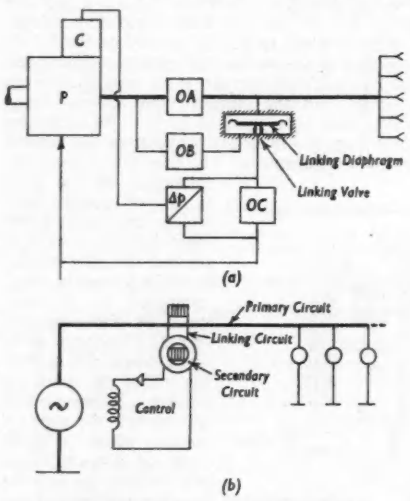


Fig. 11—Proportional flow control

The principle of the linking device, equivalent to the current transformer of the electrical engineer, is seen in Fig. 10. It comprises two orifices, a primary one in the main circuit and a secondary one in the secondary or control circuit. A linking diaphragm, subject to any difference between the two pressure drops, controls the area of an additional orifice in the secondary circuit in such a way that the two pressure drops are equal. In this case the secondary flow is related to the primary flow by the area of the two orifices and, as the secondary flow passes to suction—the equivalent of the electrical engineer's "earth"—all metering can be carried out at "earth" potential. Further, as the secondary flow is relatively small, trimming controls can easily be interposed in the circuit.

Analysis of the circuit shows that there are twelve practicable (and four unpracticable)



a—Hydraulic system. b—Electrical analogue.

Fig. 10—Principle of proportional flow control

methods of associating the functions P_1 and θ with the three orifices, *A*, *B*, and *C*, and the sensing device, so that the designer has a wide choice in the design of the control system. In an arrangement used at present and shown in Fig. 11 the *A*, or primary orifice, is made a function of θ, the *B*, or secondary orifice, is fixed, and the pressure drop across the metering orifice is equated to P_1. This arrangement has the psychological advantage that control is by a throttle valve in the main circuit, but it does introduce certain difficulties in the secondary system in view of the relatively small flows and pressure drops involved under high altitude conditions.

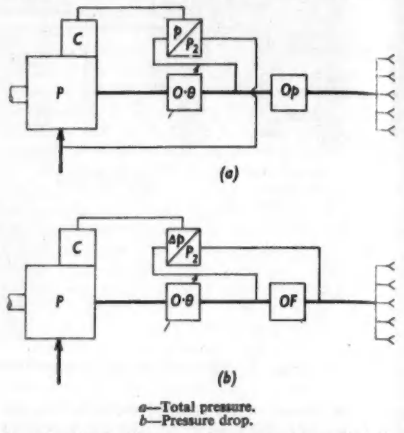
While the proportional flow system is attractive on the score of avoidance of metering on the high-pressure line and the ease with which trimming orifices can be inserted to cover speed and temperature trims, it does tend to introduce additional delays in the circuit, and care must be taken to avoid cavitation in the low-pressure orifices. High-pressure metering is generally not liable to cavitation troubles.

Acceleration Controls

In the early days of centrifugal compressors of robust construction it was left to the pilot to use discretion in opening the throttle, and so avoid either surging or possible flame extinction as a result of giving the engine too much fuel. At the present time, however, some form of acceleration control is essential. Not only are modern axial engines more liable to surge if overfuelled on acceleration but also the excess of fuel which the pump can deliver is greater owing to the necessary allowance for fuelling at high-flight speed and to the fact that the aircraft has to operate at greater altitudes.

In addition to the danger of surging, with its resultant possible flame extinction and/or damage to the engine, experience has shown that the rapid temperature changes during acceleration, and particularly the presence of excessive transient temperatures, have a very significant effect on flame tube, and probably on turbine life. The presence of excessive temperatures can be avoided either by the use of a temperature control, that is a control responsive to jet-pipe temperature, or by a fuel/air ratio control. The latter is generally the better method of attack, as it tackles the problem at its source, while the former cannot possibly act until the temperature has been attained, and is affected by the time lag and response rate of thermocouples and servo systems.

On the other hand, conditions can conceivably arise, as, for example, mechanical damage to combustion systems, allowing an escape of air



a—Total pressure.
b—Pressure drop.

Fig. 13—Block diagram of pressure type of air/fuel control

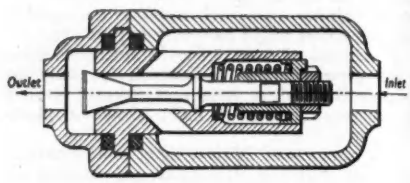


Fig. 14—Pressurising valve ("floating carrot")

and resultant local high fuel/air ratio, and temperature, where a fuel/air ratio based on total air flow would not give any protection.

Although direct temperature controls are employed largely as over-rides, the form of acceleration controller at present in general use is based on the fact that under normal conditions the nozzle guide vanes are operated in the "choked" condition, so that at a given temperature the air mass flow is proportional to the absolute pressure. If, therefore, the fuel flow is made proportional to P_2, the absolute blower pressure, the temperature in the combustion chambers will, subject to relatively small corrections for inlet temperature, compressor temperature rise, and combustion efficiency, be sensibly constant.

There are two basic methods of achieving this

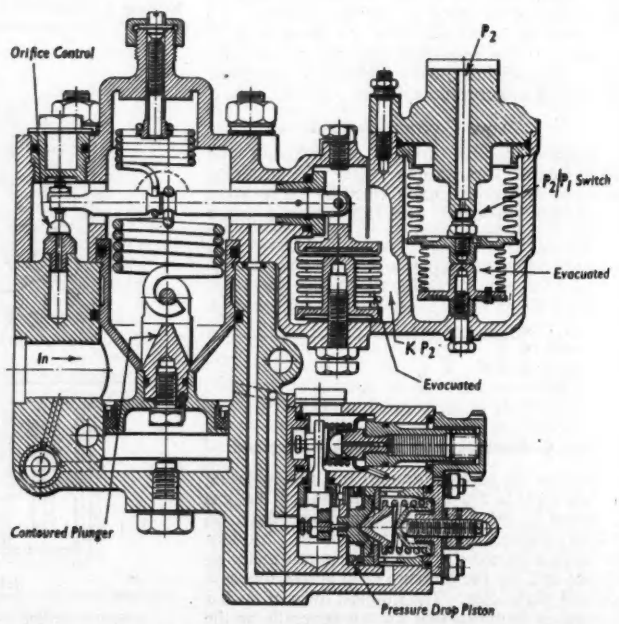


Fig. 12—Acceleration control with P_2/P_1 switch

result : in the first, a pressure or pressure drop proportional to fuel flow is equated to P_2 and the error signal is applied to the pump servo system ; in the second, the area of a metering orifice in the fuel line is made proportional to P_2 and the pressure drop is balanced against a set spring loading. The former is the simpler and was the one originally employed. This again can take two forms, the first, employing the total pressure drop in the circuit including the sprayers shown in diagrammatic form in Fig. 12*a*, the second, employing a metering orifice in the fuel line, the area of which is made proportional to the square root of the flow, shown in Fig. 12*b*. Such a metering orifice can be constructed with a

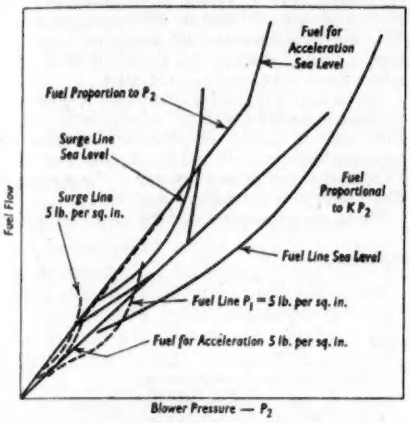

Fuel for Acceleration Sea Level
Fuel Proportion to P_2
Surge Line Sea Level
Surge Line 5 lb. per sq. in.
Fuel Proportional to K P_2
Fuel Line Sea Level
Fuel Line P_1 = 5 lb. per sq. in.
Fuel for Acceleration 5 lb. per sq. in.
Fuel Flow
Blower Pressure — P_2

Fig. 15—Relation of fuel to blower pressure

spring-loaded contoured plug moving axially relatively to the orifice itself, a device known familiarly as a "floating carrot." The actual construction of such a unit is shown in Fig. 13.

The chief troubles with this system are those associated with the friction and hysteresis of the moving member and the difficulty of matching contour and spring rate. These difficulties are increased by the large ranges in flow and pressure drop with which the system has to deal.

The second arrangement is shown in Fig. 14. This again uses a contoured plunger sliding in an orifice, but the position of the plunger is determined through a subsidiary servo system. The method of positioning the plunger is similar to that shown in Fig. 8, where an orifice was made proportional to P_1, but in this case the bellows are subject to P_2 and the orifice area is therefore proportional to this quantity. The pressure drop across the orifice is equated directly to a set spring to control the position of the main pump servo system.

Fig. 16 gives oscillographic records showing the changes in speed, fuel pressure, and jet-pipe temperature of a typical engine when undergoing acceleration under the control of a mechanism of this type.

On many modern engines with axial compressors it is not sufficient to control during acceleration on a constant temperature or fuel/air ratio only. The operating conditions over a range of speed between idling and cruising correspond to relatively low combustion temperature, and an increase in fuel and combustion temperature, to the figure which would be permitted by a fuel/air ratio control set to operate at a constant value appropriate to full speed conditions would inevitably lead to stalling and surging of the compressor. It becomes necessary, therefore, to make the permitted fuel/air ratio a function of engine speed or more accurately of $N/\sqrt{T}$. For an engine operating at one altitude only, this could be done by suitably contouring the plunger in the controller, as any desired relation between fuel flow and P_2, that is, between fuel and air, can be provided.

This expedient is, however, not possible on an aircraft engine, as non-dimensional relations have to be complied with and any adjustment of the fuel/air ratio to prevent surging must be a function of the non-dimensional parameter P_2/P_1 and not of P_2 itself. This can be effected by supplying the P_2 bellows in the acceleration control unit not from P_2 directly but from an air potentiometer system, the tapping point of which is controlled by the ratio of P_2 to P_1. In practice this can be simplified to a pressure switch operated by the ratio of P_2 to P_1 which changes the tapping at a given point; such a switch is shown in the drawing of Fig. 14. This can be more clearly seen by reference to Fig. 15, where the operating conditions are shown for a typical engine at sea level and altitude conditions. The curves show the fuel required by the engine and also the fuel value at which compressor stall occurs, plotted against values of P_2. It will be at once evident that any system which made fuel a linear function of P_2, would either give insufficient fuel at high speeds or would lead to stalling at lower ones. The ideal solution, is of course, to make the fuel follow a curve just below the stall line of the compressor, but the compromise, indicated by the thick black line, which is obtainable by the use of a pressure ratio switch, forms a satisfactory compromise. Ths last portion of the plunger profile, which is operative only under sea-level conditions, is further modified as indicated in order to permit still faster acceleration over the last portion of the operating range where operating conditions are well away from the stall line. The fact that this amount of overfuelling would be associated with temperatures above the normal is not significant in view of the very rapid acceleration under these conditions and the extremely short time during which the overfuelling can last.

As a result of the necessity for safeguarding an engine during acceleration and manœuvring and of the damage which can occur if overfuelling is permitted, present-day thinking lies in the direction of giving greater emphasis to the acceleration or overfuelling control. The underlying principle is to provide a control system which at any speed and altitude will give the engine the maximum fuel which it can accept without surging or overheating. Left to itself, under the action of this control the engine will accelerate until it is overridden by some other control, which then becomes operative. In the case of a control of the type described which is responsive to P_2, an obvious way of doing this would be to set a limit to the value of P_2, which could be impressed on the control. A simple relief valve is not, however, suitable, as it is not the absolute value of P_2 which would form the limit but the ratio of P_2/P_1. A modification of the pressure ratio switch will obviously perform such a function.

Other forms of control of this type have been proposed and tested from time to time. An acceleration control in which the fuel is made proportional to $(P_2+kP_1)N$, where k is a suitable constant and N the engine speed, has given promising results. This control is easily obtained by equating the pressure drop across a fuel-metering orifice, whose area is proportional to P_2+kP_1, to the force given by a centrifugal governor which is proportional to N^2.

In two spool engines, that is engines with two separate compressors each associated with its own turbine, the intermediate pressure stage between the compressors often forms a useful parameter for controls of this type.

It should be noted that since P_2/P_1 is also a function of $N/\sqrt{T}$, the necessity for temperature correction of such controls does not arise.

Measurement of Steam Temperatures in Power Stations

A PAPER on "The Measurement of Steam Temperatures in Power Stations," by D. H. Lucas and M. E. Peplow (Research Laboratories of the Central Electricity Authority), was presented at the Institution of Electrical Engineers in London on December 14th. The following abstracts from the paper summarise the practical problems involved in making such measurements and give the results obtained at Deptford West power station where an experiment was done to measure the change in temperature across the section of a steam pipe after a junction. The authors' theoretical analysis of the problems involved in measuring steam temperatures in pipes are not included in these abstracts.

A study of thermometers in pockets in industrial plant has been made by W. Fishwick* and by A. R. Aikman, J. McMillan and A. W. Morrison.† The conditions in the steam pipes of a power station are in a class alone, and the accurate measurement of temperatures in these circumstances is worthy of special study. It is of importance because the measurement and maintenance of efficiency in steam turbines depends on it and because recently, with the use of higher steam temperatures, the protection of pipe material from overheating has become vital. Errors in measuring steam temperature can occur for the following reasons :

(*a*) The steam temperature may not be uniform and may be different at the measuring point from the true average. It has been suggested that two supplies of steam to a pipe do not mix readily and therefore that any initial temperature difference may persist and cause errors in measurement. It has also been suggested that even in a long, single pipe the temperature distribution may not be uniform.

(*b*) The pocket containing the measuring instrument may not achieve the temperature of the steam.

(*c*) The measuring instrument may not achieve the temperature of the pocket.

(*d*) The measuring instrument may be inaccurate.

(*e*) It may have a slow response.

All these points are considered theoretically (in the paper) and results are given for a range of normal conditions. Practical work was carried out at Deptford West power station to confirm the theoretical findings.

Practical Work

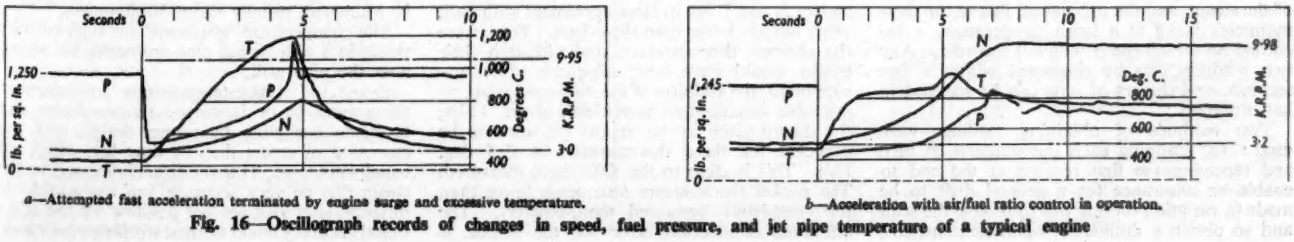
An experiment was carried out at Deptford West to measure temperature variation, if any, across a steam pipe after a junction and to compare the readings of thermometers immersed in the steam with those of a thermometer placed in a pocket. The conditions were as follows :

Steam pressure	400 lb per square inch
Steam temperature	775 deg. Fah.
Pipe diameter (internal)	13in
Pipe area	0·92 square foot.
Steam flow rate	140×10^3 lb per hour
Mass flow rate	152×10^3 lb per square-foot-hour
Steam specific gravity...	0·0095
Steam velocity	65ft per second
Pipe lagging	3in magnesia plastic

Experimental Arrangement.—It was hoped to use a pipe with a flanged joint to enable insertions to be made through a joint ring, but the only suitable pipes were of all-welded construction. To avoid the delay and cost of welding-in a special section, it was decided to insert the

* Fishwick, W., "Time-lags in Thermometer Pockets," *Transactions of the Society of Instrument Technology*, 1952, 4 No. 1, page 29.

† Aikman, A. R., McMillan, J., and Morrison, A. W., "Static and Dynamic Performance of Sheathed Industrial Thermometers," *Ibid.*, 5, No. 4, page 138.



a—Attempted fast acceleration terminated by engine surge and excessive temperature.

b—Acceleration with air/fuel ratio control in operation.

Fig. 16—Oscillograph records of changes in speed, fuel pressure, and jet pipe temperature of a typical engine

thermometers into a steam pipe by means of screwed plugs, fitted into pocket holes in the pipe. The boiler chosen for the work was No. 18 at Deptford West, which had a number of suitable thermometer pockets. The two steam pipes from the boiler join a common pipe at a point 20ft from the boiler unit.

The difference in steam temperature from the two feed pipes was measured with differential chromel-alumel couples inserted in two deep thermometer pockets. The steam temperature in the common pipe was measured with resistance thermometers. One was placed in a stainless-steel pocket, 5in long, $\frac{1}{16}$in inside diameter and $\frac{11}{16}$in outside diameter; eight others were introduced into the steam by means of two $\frac{3}{4}$in B.S.P. plugs, one inserted horizontally and the other vertically, so that the measuring points were well distributed over the pipe cross-section.

[The thermometers in one plug were designated A, B, C, D, and those in the other plug, E, F, G, H. The immersion distances of these thermometers (measured radially) were as follows: A and E, 1$\frac{1}{2}$in; B and F, 4$\frac{1}{2}$in; C and G, 8$\frac{1}{2}$in; D and H, 11$\frac{1}{2}$in.]

The active element of the resistance thermometer is $\frac{1}{4}$in in length and is placed very near the tip of a stainless steel tube $\frac{1}{4}$in in diameter and with a wall thickness of 0·028in except at the element, where it is 0·014in. The first time the experiment was attempted calibration of the thermometers was lost during their time in the steam pipe and in some cases they became open-circuited. This was attributed by the makers to vibration of the thermometers in the steam flow and to ingress of steam. In consequence, for the second attempt the thermometers were supported by mild steel tubes and the tips were welded instead of being brazed. The experiment was carried out immediately after insertion. A week later the thermometers were removed from the steam pipe and recalibrated. Only the two longest thermometers had changed calibration appreciably and the change represented less than 1 deg. Fah. in each case. There were appreciable changes, however, in the insulation resistance of several thermometers, but it is fairly certain that this occurred in the period after the conclusion of the experiment.

The measuring circuit consists of a Wheatstone bridge with a resistance thermometer as the unknown arm. Each thermometer can be selected in turn by a switch. The bridge is balanced for a temperature somewhat above that of the steam, and the unbalance, due to the thermometers being at a lower temperature, is recorded on a high-speed millivolt recorder. Any two readings can be compared within a few seconds, and the set of nine can be scanned in half a minute.

Two methods of obtaining readings were used: (*a*) scanning each thermometer in turn and repeating the first reading at the end to enable an allowance for a general drift to be made (a variation on this was to reverse the scan and so obtain a double set of measurements); (*b*) scanning so that one particular thermometer was read at the start and again after each of the other thermometers was selected.

The difference in feed-pipe temperatures was read at the start and at the end of each run. At the end of a run the bridge was unbalanced by a few ohms to give a calibration signal on the recorder chart. Full sensitivity gave a deflection of 22 divisions (1$\frac{1}{2}$in) per deg. Fah., and so was adequate for the present work.

Precautions.—The following were taken:

(*a*) the strength of the thermometers was computed. A safety factor of ten at 400 deg. Cent was found.

(*b*) The silver soldered plug assembly was pressure-tested.

(*c*) The remote end of each thermometer was kept below 200 deg. Cent. to prevent the melting of soft solder and deterioration of the leads. A minimum projection of 3in above the steam-pipe lagging is required.

(*d*) Thermal electromotive forces were avoided in the bridge circuit.

(*e*) A selector switch of negligible contact resistance was used.

(*f*) The bridge current was made a few milliamperes only, in order to keep self-heating error in the thermometer below 0·2 deg. Fah.

(*g*) The thermometers were compared at 60 deg. Fah., at 212 deg. Fah. and at the working temperature before and after use. This calibration could be repeated to within ±0·2 deg. Fah., and the spread between thermometers was ±0·7 deg. Fah. The thermometers were recalibrated at room and steam temperatures after silver-soldering into the plugs.

Measurements were commenced before the boiler came on load and were continued as the boiler gradually took up normal working and then operated under steady conditions.

All temperature readings were compared with the reading of thermometer F, which was ideally placed for accurate measurement and had no measurement change of calibration after the experiment. The results are tabulated above.

Discussion of Results.—It is apparent that when the steam flow was low there were considerable differences between the thermometers. As the steam flow rate increased the readings agreed more and more closely, until under normal conditions six of the thermometers agreed within ±0·35 deg. Fah. This supports the proposition that, except near the walls of the pipe, the steam temperature is very nearly uniform. The thermometers A and E are in close agreement with each other but are lower than the others. These were the shortest thermometers, and although their length would have been adequate while unsupported, the addition of the mild-steel supporting tubes produced an appreciable error. Using the theory given in this report the error to be expected for these thermometers is 0·5 deg. Fah. This is close to the differences measured, The pocket thermometer also reads lower than the completely immersed thermometers. The estimated conduction error for the pocket is negligible; the estimated error between pocket and thermometer is also negligible, but the radiation error is estimated to be 0·5 deg. Fah. greater for the pocket than for the more slender thermometers. This again agrees well with the measured difference. It must be pointed out that the lagging was removed from the pipe in the measurement region. The errors measured, therefore, although small, are larger than would be experienced under normally good lagging conditions.

Although there were considerable differences in temperature between the two supplies of steam, there is no evidence that this difference has persisted in any degree as far as the measuring point. There is also no evidence that a change in the temperature difference produces a change in the temperature pattern at the measuring point. This supports the view that mixing in a straight pipe is slower than in the Deptford West case, where there were bends in the pipe.

It was found that when the steam temperature varied sinusoidally with an amplitude of 9 deg. Fah. and a period of eighteen minutes the measured temperature had an amplitude of 8 deg. Fah. and a lag of one minute. The maximum disagreement was nearly 3 deg. Fah.

Using the expression derived in (*a*) of section 12.8 of the paper (not reproduced here), the time lag of the immersed thermometer has been estimated to be a few seconds. Its errors due to lag are therefore negligible. Using the expressions derived in (*b*) and (*c*) of the same section, the time-constant for the pocket thermometer was in both cases found to be 0·7 minute. A similar measurement was made with the thermometer placed in the pocket without metallic contact; the time-constant was one minute. This demonstrates that metallic contact in practice is useful but does not greatly outweigh the heat transfer due to radiation and convection. Under steady conditions it made no difference to the temperature reading whether there was metallic contact or not.

If the temperature is fluctuating the error may be estimated from the value of $t' \times \max dT_s/dt$, if t' is small compared with the time of the temperature cycle. This will tend to exaggerate the error if anything. It may be estimated more accurately as in (*c*) of section 12.8.

Results of Steam Temperature Measurements at Deptford West Power Station

Time, hours GMT	Run	Temp. diff., deg. Fah.	F, deg. Fah.	Temperature relative to F									Remarks
				A, deg. Fah.	B, deg. Fah.	C, deg. Fah.	D, deg. Fah.	E, deg. Fah.	F, deg. Fah.	G, deg. Fah.	H, deg. Fah.	P, deg. Fah.	
0625	1	12	450	—21	—0·3	—2·0	—16	—32	0	0	—0·3	—3·2	Steam stagnant
0630	2	—											Start of steam flow
0635	3	30	662	—16·6	—11·4	—3·2	—1·4	—6·5	0	+0·5	1·3	—28	Steam flow increasing
0638	4	34	705	—4·7	—0·4	+0·2	+0·1	—5·4	0	—0·4	—0·3	—13·1	Steam flow increasing
0640	5	36	712	—4·0	0	0	+0·2	—4·5	0	—0·3	—J·5	—7·7	Steam flow increasing
0645	6*a*	36	722	—2·9	+0·1	+0·2	+0·3	—6·5	0	—0·4	—0·3	—4·5	Steam flow increasing
—	6*b*	36	722	—2·3	+0·3	0	+0·4	—4·7	0	—0·2	0	—3·8	Steam flow increasing
0655	7	—	—										Steam flow increasing
0715	8	17	802	—1·8	+0·1	+0·3	+0·7	—2·2	0	—0·2	+0·5	—3·1	Steam flow increasing
—	9	—	—										Steam flow increasing
0721	10*a*	12	802	—1·1	+0·4	+0·5	+0·7	—1·3	0	0	+0·5	—0·5	Steam flow increasing
—	10*b*	11	802	—1·1	+0·2	+0·3	+0·5	—1·3	0	0	+0·5	0	Steam flow increasing
—	11	—	—										Steam flow increasing
0725	12*a*	11	802	—0·7	+0·4	+0·2	+0·5	—0·3	0	+0·4	+0·5	—0·5	Flow steady at 140×10^3 lb/hour
—	12*b*	11	802	—0·7	+0·3	+0·4	+0·7	—0·3	0	+0·4	+0·5	—0·7	
—	13	—	—										
0800	14	12	802	—0·9	0	+0·1	+0·5	—0·9	0	+0·5	+0·3	—0·7	
0850	16	28	795	—0·7	0	0	+0·4	—0·5	0	+0·5	+0·3	0	Pocket thermometer not in metallic contact
0915	18	—6	786	—0·4	0	+0·2	+0·7	—0·2	0	—	+0·9	+0·9	
1110	20	15	786	—0·7	—0·2	+0·1	+0·7	—0·5	0	+0·7	+0·5	—0·3	Pocket thermometer not in metallic contact
1325	21	35	788	—0·2	+0·4	+0·5	+1·1	—0·2	0	+0·7	+0·7	+0·2	Pocket thermometer not in metallic contact
1330	22	36	781	—0·7	0	+0·1	+0·9	—0·7	0	+0·9	+0·5	0	Pocket thermometer not in metallic contact
1430	23	42	783	—0·9	+0·2	+0·1	+0·9	—1·1	0	+0·5	+0·5	—0·7	Pocket thermometer not in metallic contact
—	—	—	—	—0·7	0·1	0·2	0·7	—0·6	0	0·5	0·6	—0·2	Average of last nine runs

Conclusions

Two streams of steam entering a single pipe are thoroughly mixed in a distance which can be estimated, usually about 30 diameters.

The temperature gradients in high-velocity steam in a well lagged pipe are negligible except near the pipe wall.

Errors of steam-temperature measurement using pockets or immersed thermometers can be made negligible by proper design, with the exception of errors due to time lag, which are usually not large. Thermometers immersed in the steam can be very accurate, but the additional difficulty and risk are not justified by the additional accuracy under normal working conditions.

Tensile Stripping Tests on B.S.W. $\frac{3}{4}$in - 10 T.P.I. Threads*

By J. E. FIELD

The object of the tests was to determine the relationship between nut height and static stripping strength of assemblies of $\frac{3}{4}$ B.S.W. nuts and bolts from steels to Codes A, P, and T, B.S. 1768–1951, in different combinations. Static stripping tests have been carried out on high tensile (EN 16T) steel bolts and nuts, high tensile bolts with mild steel nuts (to strip the nuts), and low tensile steel (EN 7) bolts with high tensile nuts (to strip the bolts). The effect of end-conditions has also been examined by testing assemblies with and without bolt threads protruding beyond the nut face. The conclusions reached are that the static stripping strength of a bolt and nut assembly is proportional to the height of the nut irrespective of whether the bolt threads or the nut threads are stripped ; and that for a given height of nut, the strength of a combination assembled with the nut face flush with the end of the bolt is less by about 10 per cent than that of a combination with one or more threads protruding from the nut. The difference is greater when the nut threads strip.

THE tensile stripping strength of threaded bolts is of importance to designers in determining the length of engagement required when using screw threads on load carrying members. An interest in stripping strength and its relationship with nut height has also recently been expressed by the Screw Thread and Gauging Committees of the British Standards Institution in connection with possible unified standardisation of British and American screw thread gauging practice. In view of the scarcity of experimental evidence yet available on this subject it was decided to employ some surplus specimens in the form of double ended $\frac{3}{4}$in B.S.W. studs and nuts, from a previous screw thread research, to obtain some relevant data.

Materials

Each test piece consisted of a double-ended stud about 4in in length with $\frac{3}{4}$in diameter threads fitted with circular nuts $1\frac{1}{2}$in in external diameter. Each stud (referred to in the following as a " bolt ") was assembled with one nut of full height (= thread diameter) on one end, and one of reduced height at the other end. The height of this nut, at which failure would generally be expected to occur, was varied for the main series of tests. The threads were all 10 T.P.I. and, apart from one short series of tests, in which 45 deg. thread angles were employed, they were all of 55 deg. B.S.W. form. The threads were accurate in form and the effective diameter clearance between nut and bolt in no case exceeded 0·004in. The bolt steels conformed to Codes P. and T. in Table V, Appendix A, of B.S. 1768—1951, while those for the nuts conformed to Codes A and T in Table VI of this standard. Actual values of tensile strength and Vickers pyramid hardness are given in the tables of results.

Method of Test

The tests were carried out in a hydraulically operated tensile testing machine of 30 tons capacity. In each test, load was applied to the inner faces of the nuts by means of adaptors, one of which is illustrated in Fig. 1, stressing the body of the bolt in tension until the threads stripped or the bolt failed across the core.

Spherical seatings were incorporated in the loading system. Initially three series of tests (designated A, B and C in Table I) were carried out to investigate the relationship between stripping strength and length of engagement of threads. In series A the bolt was of medium tensile steel and the nut of high tensile steel. In series B the bolt and nut were both of high tensile steel. In series C the bolt was of high tensile steel and the nut of mild steel. In each series the height of the nut was varied from about 0·1in up to the full diameter of the bolt.

In these first tests the nut was assembled on the bolt with the end thread of the bolt protruding beyond the nut. This was done partly because a nut is usually assembled on a bolt with one or more bolt threads protruding and partly also to avoid use of the end thread of the bolt which was incomplete in the specimens used, due to " pointing " of the thread blank, and to the fact that the thread helix lay at an angle to the end face of the bolt.

Since the condition where a nut is assembled flush with the end of a bolt might sometimes occur in practice, it was decided to obtain an idea of the difference in stripping loads for bolts assembled flush with the nut and with one bolt thread protruding. For these tests, referred to as series D and E, all the bolts were faced off at the end so as to remove the low diameter portion due to " pointing," but leaving the end thread of the helix where it ran into the end face of the bolt. The tests of series D were made on 55 deg. threads, using the same combination of materials as series C and employing two nut heights. The tests of series E employed the same combination of materials as series A, using a single nut height which would ensure stripping of the bolt ; these tests, however, were made on 45 deg. threads, no suitable. 55 deg. threaded specimens being available. In all these tests, for each nut height employed, at least two tests were made with the bolt end flush with the face of the nut, and two with the bolt protruding one pitch beyond the nut. An additional test in series D was made with four threads protruding to verify that further unengaged threads, over and above the one, had no additional influence on the stripping load. The results of the tests in series A, B and C are given in Table I and those of series D and E in Table II.

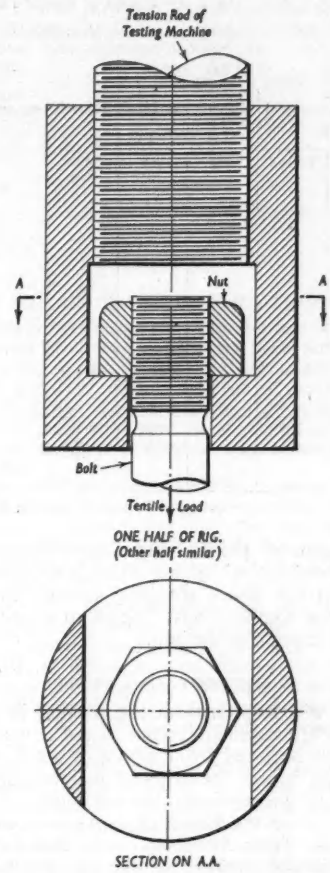


Fig. 1—Rig for tensile stripping tests on bolt and nut assemblies

The stripping loads measured in the tests of series A to D are shown plotted against the height of the nut, expressed as a fraction of the bolt diameter in Fig. 2. It will be noted that tests of series D made with one bolt thread protruding are similar in all respects to those of series C, and can be included with that series in drawing a line

TABLE I—*Results of Tensile Tests on $\frac{3}{4}$–10 B.S.W. Nut and Bolt Assemblies—Series A, B and C*

Series	Details of bolt: Material	Details of bolt: Tensile strength, tons per sq in	Details of bolt: Diamond pyramid hardness number HD/30	Details of nut: Material	Details of nut: Tensile strength, tons per sq in	Details of nut: Diamond pyramid hardness number HD/30	Height of nut: Inches	Height of nut: Fraction of D	Maximum stripping load, tons	Mode of failure*
A	3S1	39	200	Similar to EN16T	62	310	0·112$_8$	0·150	4·2$_8$	Bolt threads stripped
							0·193	0·257	7·4	Bolt threads stripped
							0·223$_8$	0·298	8·5	Bolt threads stripped
							0·273	0·364	10·3$_8$	Bolt threads stripped
							0·312	0·416	11·7$_8$	Bolt threads stripped
							0·750	1·000	13·0	Bolt failed across core, outside nut
B	EN16T	62½	310	Similar to EN16T	62	310	0·121	0·161	6·2$_8$	Bolt threads stripped
							0·225	0·300	11·8	Bolt threads stripped
							0·300	0·400	16·1$_8$	Bolt threads stripped
							0·355	0·473	18·6$_8$	Bolt threads stripped
							0·750	1·000	20·7	Bolt failed across core, outside nut
C	EN16T	62½	310	Mild steel	28	120	0·100	0·133	2·7$_8$	Nut threads stripped
							0·100	0·133	2·7$_8$	Nut threads stripped
							0·379	0·505	11·2	Nut threads stripped
							0·379	0·505	11·6	Nut threads stripped
							0·450	0·600	12·4	Nut threads stripped
							0·450	0·600	12·9$_8$	Nut threads stripped
							0·600	0·800	17·0$_8$	Nut threads stripped
							0·600	0·800	17·1	Nut threads stripped
							0·750	1·000	20·7	Bolt failed across core, outside nut

* Where the bolt threads stripped, there was slight damage to the thin end threads of the nuts. Where the nut threads stripped, there was only slight burring of the crests of the bolt threads.

* Communication from the Mechanical Engineering Research Laboratory, East Kilbride.

TABLE II—*Results of Tensile Tests on ¾in×10 T.P.I. Nut and Bolt Assemblies*

(Tests to determine effect of bolt threads protruding beyond nut)

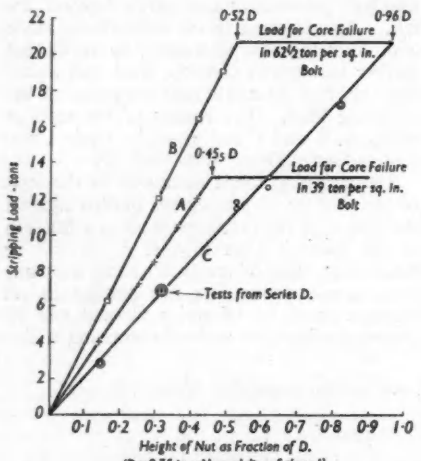
Series	Bolt: Material	Bolt: Tensile strength, tons per sq in	Bolt: Vickers hardness number HD/30	Nut: Material	Nut: Tensile strength, tons per sq in	Nut: Vickers hardness number HD/30	Height of nut: Inches	Height of nut: Fraction of D	No. of bolt pitches clear of nut	Stripping load, tons	Mode of failure
D*	EN16T	62½	310	Mild steel	28	120	0·225	0·300	1	6·7	All nut threads and no bolt threads stripped
							0·225	0·300	1	$6·7_8$	
							0·225	0·300	1	$6·7_8$	
							0·225	0·300	0	5·9	Half turn of end bolt thread, and all nut threads except one turn at back stripped
							0·225	0·300	0	5·9	
							0·225	0·300	0	$5·9_8$	
							0·379	0·505	1	11·2	All nut threads and no bolt threads stripped
							0·379	0·505	1	11·6	
							0·377	0·503	4	11·4	
							0·384	0·512	0	10·2	Half turn of end bolt thread, and all nut threads except one turn at back stripped
							0·384	0·512	0	10·5	
E*	3S1	38	200	Similar to EN16T	62	310	0·399	0·532	1	12·0	Bolt threads stripped
							0·399	0·532	1	11·7	
							0·399	0·532	0	11·0	Bolt threads stripped
							0·399	0·532	0	$10·9_8$	

* Test pieces of Series D were of 55 deg. B.S.W. form ; those of Series E had 45 deg. threads.

through the points. Fig. 2 also shows the expected critical heights of nut, i.e. those for which the thread stripping strength in the various combinations is equal to the tensile core strength of the bolt.

DISCUSSION OF RESULTS

It will be seen from Fig. 2 that, in each of the three series of tests A, B and C, whether failure occurred by stripping of nut threads or bolt threads, the stripping load was approximately proportional to the height of the nut, i.e. to the length of engagement of the thread. This result was to be expected, as plastic deformation of the threads would tend to even out the non-uniform load distribution occurring under elastic conditions. An end effect of some kind would be expected, either in the bolt or in the nut, due to the lack of support for the end of the thread helix, but the lines of Fig. 2, which are a reasonably good fit to the various experimental points, all pass through the origin, indicating that any end effect present bore a constant ratio to the nut height.



\+ 39 ton/square inch bolt, 62 ton/square inch nut. Bolt stripped. Series A.
□ 62½ ton/square inch bolt, 62 ton/square inch nut. Bolt stripped. Series B.
⊙ 62½ ton/square inch bolt, 28 ton/square inch nut. Nut stripped. Series C.

Fig. 2—Relation between stripping load and nut height

For series A and B, the critical nut height in each case is approximately 0·5D ; the small difference between the two cases is probably due to the difference in the ratios of tensile strength to shear strength for the two bolt steels. (The bolt threads stripped in these cases.) The critical length of engagement should be proportional to this ratio,† which tends to increase with tensile strength (strictly with reduction in work-hardening capacity).

For series C tests, the critical height of nut is 0·96D ; under these conditions, where the nut thread stripped, the critical height would be expected, for the same bolt material, to be inversely proportional to the shear strength of the nut material, i.e. approximately to its tensile strength, taking the ratio of shear strength to tensile strength as constant. Other experience has, in fact, confirmed this, e.g. the critical height of nut for a 37 tons per square inch nut on a 62½ tons per square inch bolt would be expected to be 0·96D×28·37=0·7D, and this has been found experimentally to be so. It should be remembered that these figures for critical height of nut have been obtained in tests on ¾-10 B.S.W. threads and are not necessarily generally applicable.

From the results of series D (Table II) it will be seen that for each height of nut, the average stripping load for the nuts assembled flush with the ends of the bolts was about 12 per cent less than that for the nuts assembled so as to leave the bolt protruding by one pitch. The mode of failure in the two cases was rather different : in the latter case, the nut threads all stripped and no bolt threads stripped : in the former case, about half a turn of the end thread of the bolt stripped (being thin and unsupported by adjacent metal), and about one turn of the end thread of the nut did not strip (since only that part of it thicker than half a pitch could engage with the bolt thread). In each of the tests with one bolt thread projecting, the maximum load was attained before the nut had moved relative to the bolt by any readily discernible amount. It was therefore expected that additional projecting threads would have no influence on the stripping load, and the single test with four protruding threads confirmed this.

The results of series E show that the average stripping load for the bolts with their ends flush with the nut was about 7 per cent less than the stripping load for the bolt protruding one pitch beyond the nut. As for series D, part of the end thread of the nut would not be in engagement in the former case. In series E, however, all the bolt threads including the thin end thread, stripped in both cases, which may account for the smaller difference here between the two cases.

† Typical values are 1·01 for a 42 tons per square inch, 0·4 per cent carbon steel (normalised), and 1·11 for a 58 tons per square inch, 3½ per cent nickel-chromium steel (hardened and tempered). (Figures obtained from Gough, Pollard and Clenshaw, R. and M. 2522, of Aeronautical Research Council, 1951.)

CONCLUSIONS

The static stripping strength of a bolt and nut combination is proportional to the height of the nut, i.e. the length of engagement. This is so whether the bolt threads or the nut threads strip. The stripping strength of a bolt and nut combination, in which the nut is assembled flush with the end of the bolt, is less than that of a combination where the nut is screwed on so as to leave one or more bolt threads protruding. The difference is of the order of 10 per cent for ¾in×10 T.P.I. threads, and is greater in the case where the nut threads strip. These remarks only apply when conditions are such as to cause thread stripping instead of failure across the core of the bolt, outside the nut.

ACKNOWLEDGMENTS

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Pressurised Water Reactor as a Source of Heat for Steam Power Plants

By J. M. KAY, M.A., Ph.D., and F. J. HUTCHINSON, M.Eng., M.I.E.E.*

No. I

This paper was presented at a meeting of the Institution of Mechanical Engineers, in conjunction with the British Nuclear Energy Conference on December 14th, and long extracts are here reprinted. Apart from the contributions to the recent inaugural meeting of the conference it is the first paper to be presented to any Institution under the wing of the conference.

IN his James Clayton Lecture on "Nuclear Reactors and Power Production" (Hinton, 1954),† Sir Christopher Hinton spoke of the probable development of a number of different types of nuclear reactor forming a sequence in ascending order of thermal rating and descending order of core size. At one end of the scale there is the graphite-moderated gas-cooled reactor of the Calder Hall type. At the other extreme there is the plutonium-fuelled, fast-fission reactor.

The graphite-moderated, gas-cooled reactor is already being developed for widespread use during the first stage of the United Kingdom's nuclear power programme. It has many advantages, particularly in its ability to use natural uranium and in its inherent safety. When by-product plutonium becomes available in quantity from the early nuclear reactors, however, it will be desirable to have other reactors following on, which will be suitable for burning the by-product plutonium in conjunction with natural or depleted uranium in the most efficient way. Among the more promising possible types of thermal reactor which could be developed for use during this second stage are the sodium-cooled graphite reactor and the pressurised water-moderated reactor.

The purpose of the present paper is to examine the pressurised water reactor from the power

Notation

b—Effective perimeter of the element.
c_p—Specific heat of coolant.
d_1—Diameter of uranium rod.
d_2—Outer diameter of fuel element.
E—Young's modulus.
H—Rate of heat release per unit length at the centre.
H_0—Maximum rate of heat release per unit length at the centre.
h—Heat transfer factor.
k_c—Thermal conductivity of the material of the sheath.
k_U—Thermal conductivity of uranium fuel.
L—Length of core.
L'—Extrapolated length of core.
m—Mass flow of coolant in the channel.
N_s—Specific speed of pump.
p_θ—Hoop stress.
Q—Flow, or heat release.
T—Coolant temperature.
T_c—Surface temperature of the element.
T_1—Inlet coolant temperature.
T_2—Outlet coolant temperature.
α—Coefficient of expansion.
ΔT—Radial temperature difference through wall of sheath.
σ—Poisson's ratio.

* Kennedy and Donkin, Ltd.

† An alphabetical list of references is given in Appendix II.

plant engineer's point of view, and to consider some of the different ways in which it could be employed as a source of heat for a steam power station. The description "pressurised water reactor" will be taken to include both light-water and heavy-water-moderated reactors employing a pressurised water-cooling system. The general engineering features would be similar in either case. A heavy-water-moderated reactor, however, is capable of using natural uranium provided a calandria type of construction is employed, so that most of the moderator can be maintained at high density and, because of the rather open lattice arrangement required, it involves a rather larger diameter of core. A light-water-moderated reactor, on the other hand, must be fuelled either with enriched uranium or with a mixture of uranium and plutonium, and the ratio of moderator volume to fuel volume is much smaller than with the heavy-water reactor.

The core of a pressurised-water reactor will consist of a cylindrical assembly of fuel elements arranged in lattice formation and housed inside a pressure vessel. Each fuel element will normally be located inside a coolant channel or duct, and water will be circulated at a fairly high velocity to secure the required rate of heat removal. The moderator and coolant water must normally be pressurised to prevent the occurrence of boiling inside the core.

It is a feature of every type of nuclear reactor that the fuel element presents the most difficult problem of any part of the design. The fuel itself may take the form of metallic uranium, an alloy of uranium, or the oxide UO_2. As in the case of other reactors, the fuel must be protected by means of a can or sheath to prevent oxidation (in the case of metallic fuel) and to prevent the escape of fission products. The canning material must meet stringent mechanical, nuclear and chemical requirements. It is not within the scope of this paper, however, to discuss the particular problems of the fuel element and core design. The approach adopted here is to look at the reactor as part of a steam power plant, to put some engineering limits on rates of heat removal, reactor pressures, coolant temperatures, &c., and, finally, to estimate the practicable range of steam conditions and turbine output. This having been done, it is easier to decide whether the pressurised-water reactor is of sufficient potential merit to justify the development work necessary to overcome the metallurgical and nuclear problems of the fuel element and core design and, above all, the problem of corrosion.

The Nuclear Reactor as a Source of Heat

There is now sufficient published information on neutron diffusion theory and the properties of uranium to enable engineering calculations to be made regarding the sizes of certain types of nuclear reactor and the distribution of the heat

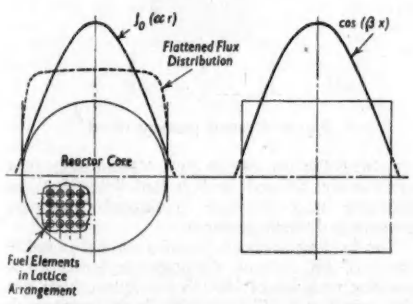


Fig. 1—Heat release in a reactor core

release (Littler and Raffle, 1955 ; Glasstone and Edlund, 1952). Consider the case of a thermal reactor with a cylindrical core and reflector. The heat release per unit volume of core will be given by an equation of the form :

$$Q = Q_{max} J_0(\alpha r) \cos(\beta x) \quad . \quad . \quad . \quad . \quad (1)$$

that is, the heat release follows a Bessel function distribution with radius, and a cosine distribution with axial distance (Fig. 1).

In many reactor designs the radial distribution of the neutron flux and heat release is deliberately altered by "flattening." This can be achieved by using two different types of fuel element with different degrees of enrichment, by introducing neutron-absorbing material in the central region of the core, or by other devices. From an engineering point of view it is obviously desirable to avoid a large peak in the heat release at the centre of the core. It will therefore be reasonable to confine the investigation of the heat transfer between fuel element and coolant to a single channel,

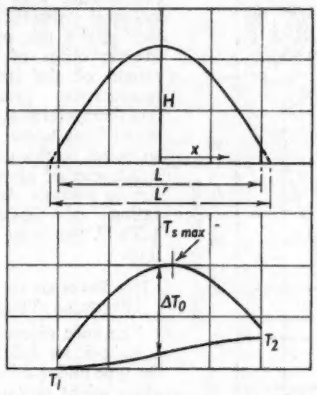


Fig. 2—Heat release and temperature distribution in a channel

and to assume a channel rating equal to the radial average for the whole core.

The axial distribution of neutron flux and heat release may also be subject to distortion if control rods are employed which operate by axial movement into and out of the core. However, for the purposes of a preliminary calculation it will be sufficient to take the normal cosine distribution—that is, the heat release per unit length for a single channel will be given by

$$H = H_0 \cos \frac{\pi x}{L'} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where H_0 is the maximum rate of heat release per unit length at the centre of the channel ; x, is the axial distance measured from the centre and L' is the extrapolated length of the core.

For heat transfer from the surface of a fuel element to the coolant, the heat flux q will be given by

$$q = \frac{H}{b} = h(T_s - T)$$

and hence

$$T_s - T = \frac{H_0}{bh} \cos \frac{\pi x}{L'} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where T_s is the surface temperature of the element ; T is the coolant temperature ; h is the heat transfer factor, and b is the effective perimeter of the element.

The temperature rise of the coolant in flowing along a channel is given by

$$mc_p dT = H dx$$

or

$$\frac{dT}{dx} = \frac{H_0}{mc_p} \cos \frac{\pi x}{L'} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and hence

$$T_2 - T_1 = \frac{H_0}{mc_p} \frac{2L'}{\pi} \sin \frac{\pi L}{2L'} \quad . \quad . \quad . \quad (5)$$

where T_1 is the inlet coolant temperature ; T_2 is the outlet coolant temperature ; m is the mass flow of coolant in the channel, and c_p is the specific heat of the coolant.

The resulting temperature distribution along the surface of the fuel element is shown for a typical case in Fig. 2.

If boiling of the water inside the core is to be prevented, the maximum surface temperature of a fuel element must not be allowed to rise above the saturation temperature at the reactor pressure. This limitation will fix the permissible temperature levels throughout the reactor.

The difference between the maximum surface temperature $T_{s\,max}$ and the coolant inlet temperature T_1 is of particular interest, and this is given conveniently by Ginns's equation, which can be derived from equations (3) and (4).

$$T_{s\,max} - T_1 = \tfrac{1}{2}(T_2 - T_1) + \sqrt{\Delta T_0^2 + \left\{ \frac{\tfrac{1}{2}(T_2 - T_1)}{\sin \frac{\pi L}{2L'}} \right\}^2} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where

ΔT_0 is the value of $(T_s - T)$ at $x = 0$;

that is,

$$\Delta T_0 = H_0 / bh$$

Size and Rating of Fuel Elements

It is convenient to start with the case of a fuel element of circular cross-section surrounded by an annular passage for the coolant, as shown in Fig. 3. The nuclear calculations for the core are usually based on an equivalent lattice element, or unit cell, of this type even though a different shape for the fuel element may ultimately be chosen.

The heat-transfer calculation is most easily carried out by taking a particular value for the coolant velocity, evaluating the heat-transfer factor h from the normal data for forced convection to fluids flowing in pipes and annuli, and then calculating ΔT_0 and $(T_2 - T_1)$ for various values of H_0. The Ginns's equation may then be used to give the overall temperature difference $(T_{s\,max} - T_1)$. Temperature differences may then be plotted against coolant velocity for various types of fuel element and for different values of the thermal rating. Some typical results are shown in Fig. 4 for a channel 8ft in length with circular fuel rods of $\frac{1}{2}$in, $\frac{3}{4}$in, and 1in outside diameter and with a $\frac{1}{8}$in annulus for the coolant passage. Some allowance has been made in these calculations for deterioration of the heat-transfer surfaces as a result of corrosion or deposition by the coolant. The precise value of the fouling factor to be employed in estimating the overall heat-transfer factor h will naturally depend on the material used for the fuel element cans and also on the treatment of the water.

The upper practical limit to the coolant velocity will be set by the pressure drop in the channel, and by other considerations such as erosion. The calculated loss of head for water flowing in the channel is shown by the dotted curve in

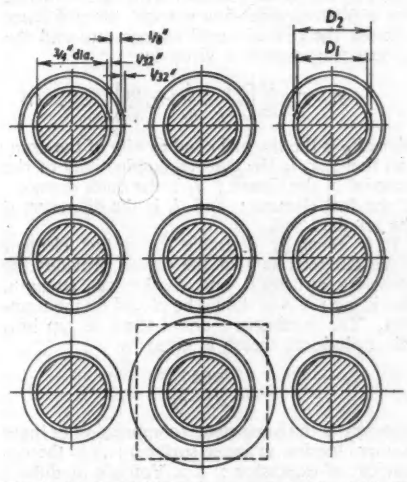


Fig. 3—Typical lattice arrangement showing fuel rods and coolant channels

Fig. 4. If the permissible coolant velocity is fixed it will be observed from Fig. 4 that, for a given temperature difference $(T_{s\,max} - T_1)$, there will be a maximum permissible fuel rating for every different shape and size of fuel element. To take an example, if the coolant velocity is limited to 25ft per second, and if the reactor design aims at a temperature difference $(T_{s\,max} - T_1)$ which is not to exceed 100 deg. Fah., the permissible heat rating of the fuel for circular rods (from Fig. 4) would be as follows :

Rod diameter, inch...	$\frac{1}{2}$	$\frac{3}{4}$	1
Million B.Th.U. per hour cubic foot ...	21·5	13·7	10·0

A light-water reactor of the type under con-

sideration might have between 40 and 50 tons of slightly enriched uranium in the core. If the design aims at a total heat output of some 500MW, the average fuel rating would have to be about 20,000,000 B.Th.U. per hour cubic foot. This could be achieved either with circular rods of slightly over ½in diameter, or by using fuel elements of a different shape altogether but having

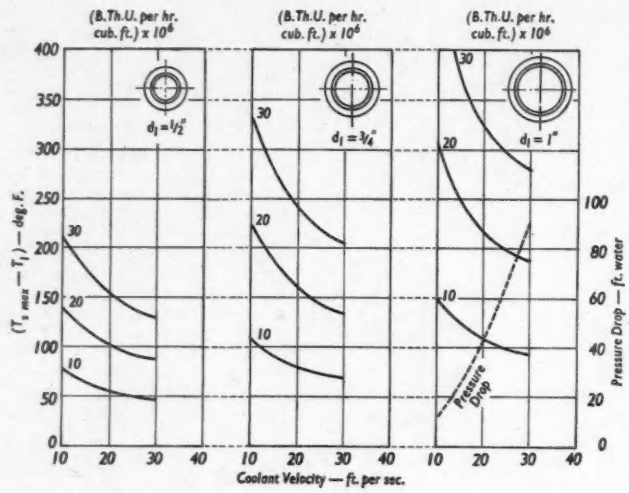

(B.Th.U. per hr. cub. ft.) x 10⁶
(B.Th.U. per hr. cub. ft.) x 10⁶
(B.Th.U. per hr. cub. ft.) x 10⁶
d₁ = ½"
d₁ = ¾"
d₁ = 1"
(T_s max − T_f) — deg. F.
Pressure Drop — ft. water
Pressure Drop
Coolant Velocity — ft. per sec.

Fig. 4—Heat-transfer calculations

an equivalent diameter of approximately ½in. The need to employ elements of small diameter, and the large number required, points to the desirability of grouping elements in clusters for convenience in charging and discharging. Some typical non-circular fuel elements are shown diagrammatically in Fig. 5. These may be compared with the particular proposals reported for different design studies (Simpson and others 1955 ; Iskenderian and others 1955 ; Harrer and others 1955.).

Having reached the provisional conclusion that a heat rating of the order of 20,000,000 B.Th.U. per hour cubic foot should be feasible as regards heat transfer, it is necessary to examine the limits imposed by heat flow within the fuel itself and the thermal stresses in the fuel elements. For a plain circular fuel element the difference between the central metal temperature and the surface temperature is given by

$$T_0 - T_s = \frac{H}{2\pi}\left[\frac{1}{2k_U} + \frac{1}{k_s}\log_e\frac{d_2}{d_1}\right] \quad . \; . \; (7)$$

where k_U is the thermal conductivity of the uranium fuel ; k_s is the thermal conductivity of the material of the sheath ; d_2 is the outer diameter of the fuel element ; and d_1 is the diameter of the uranium rod.

It is generally desirable for a fuel element to be designed so that the sheath provides the necessary structural and mechanical strength, that is, no reliance should be placed on the uranium. The maximum thermal stress set up in a thin cylindrical sheath is given by

$$p_h = \frac{\alpha E \Delta T}{2(1-\sigma)} \quad . \; . \; . \; . \; . \; (8)$$

where p_h is the hoop stress (compression at inner surface, tension at outer surface) ; α is the coefficient of expansion ; E is Young's modulus ; σ is Poisson's ratio ; and ΔT is the radial temperature difference through the wall of the sheath.

An additional hoop stress, however, may be caused by the expansion of the fuel inside the sheath.

TABLE I—*Heat Flux and Thermal Stress*

Fuel-rod diameter, inch	¼	½	1
Average value of H	27,200	61,300	109,000
Average surface heat flux	208,000	312,000	416,000
Maximum heat flux, B.Th.U. per hour square foot	312,000	468,000	624,000
$(T_0 - T_s)$ max., deg. Fah.	210	442	759
ΔT max., deg. Fah.	44·5	67·4	90
Hoop stress, tons per square inch	4·82	7·28	9·7

The results in Table I refer to an average heat rating of 20,000,000 B.Th.U. per hour cubic foot. The peak rating (at the centre of the channel) is taken to be 1·5 times the average. A stainless-steel sheath of thickness $^1/_{32}$in is assumed.

It is evident that a definite limit will be imposed on the diameter of the fuel rod for a given thermal rating, that is, the higher the rating required the smaller must be the equivalent diameter. This rating will depend, however, on the choice of materials and on the detail design of the fuel element. The above figures refer only to the simple case of a plain cylindrical element with stainless-steel sheath, but they give a fair picture of the order of magnitude of the internal temperature gradients and thermal stresses. An upper limit would have to be set in this case at a diameter of about ¾in for an average thermal rating of 20,000,000 B.Th.U. per hour cubic foot.

The Problem of the Pressure Vessel

The core diameter of a light-water reactor of the type under consideration might be between 6ft and 8ft, depending on the degree of enrichment and quantity of the fuel to be used. The core diameter of a heavy-water reactor, on the other hand, would be larger than this, owing to the greater moderator/uranium ratio required and the correspondingly more open lattice.

Taking the case of the light-water reactor and allowing for an adequate thickness of reflector surrounding the active core, a pressure vessel of diameter 9ft or 10ft would be required. The absolute temperature level in the reactor will be fixed by the permissible reactor pressure, and it is therefore necessary to determine the upper practical limit. Table II gives the wall thickness required for a fusion-welded, mild steel pressure vessel of internal diameter 10ft.

TABLE II—*Wall Thickness and Working Pressure*

Reactor working pressure, pounds per square inch	1000	1500	2000
Wall thickness, inches	5	7½	10

The 1500 lb per square inch case probably represents a reasonable upper limit, and should not involve going far outside the range of normal welding techniques or existing manufacturing capacity.

The most difficult part of the pressure vessel design will be the method of end closure. It would be desirable to have a removable end or top cover which could be opened up for major refuelling operations, protection from radiation under these conditions being provided by flooding the reactor with water to a level of some 6ft or 8ft above the top of the core. The design of a satisfactory flanged and bolted joint for the diameter and pressure envisaged, however, presents a difficult problem.

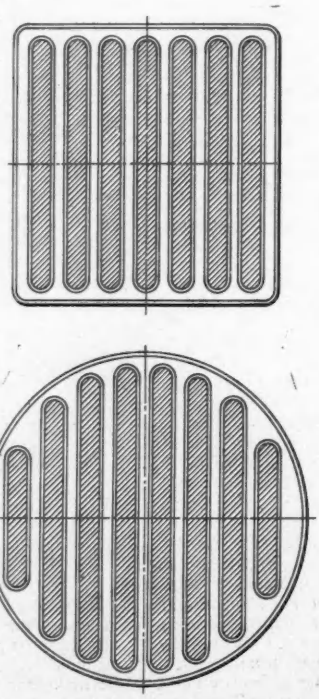


Fig. 5—Flat-strip fuel elements

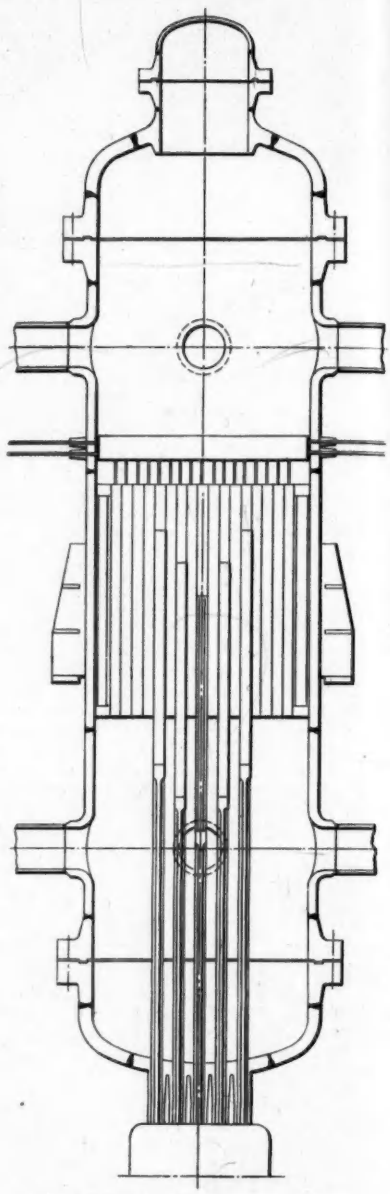


Fig. 6—Reactor pressure vessel

The leading proportions of a typical pressure vessel of 9ft internal diameter, designed for a working pressure of 1500 lb per square inch, are shown in Fig. 6. Taking 1500 lb per square inch as the limiting reactor pressure, the corresponding saturation temperature will be 596 deg. Fah. and this will fix the permissible temperature levels throughout the plant. In the limiting case, with local nucleate boiling at the hottest point on the surface of the fuel element, the permissible value of $T_{s\,max}$ would therefore be equal to the saturation temperature 596 deg. Fah. Some provision, however, must be made for departure from design conditions, and in the following analysis of the steam cycle an additional 20 deg. Fah. will be allowed—that is, the maximum surface fuel-element temperature will be taken as 576 deg. Fah.

There are various possible methods for maintaining and controlling the pressure in the reactor vessel and coolant circuit. One arrangement described (Simpson and others, 1955) involves the use of a special pressurising tank or steam dome, in which the water is heated electrically to the boiling point corresponding to the reactor pressure.

Primary Coolant Circuit and External Heat Exchangers

It has been noted that with fuel elements of approximately ½in equivalent diameter, the temperature difference ($T_{s\,max}-T_1$) could be limited to about 100 deg. Fah. at a heat rating of 20,000,000 B.Th.U. per hour cubic foot, without employing excessive water velocities. The temperature rise T_2-T_1 of the coolant in a channel will depend on the heat rating for the channel and the mass flow of water. For a given heat rating for the fuel, and for a given water velocity, the coolant

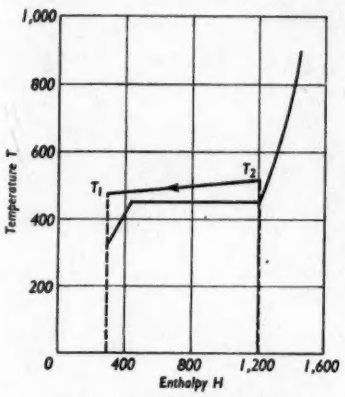


Fig. 7—Heat-transfer diagram

temperature rise T_2-T_1 will therefore depend on the geometry of the channel. In the following calculation a value of 36 deg. Fah. will be taken as a typical figure. For a 500MW reactor this would imply a total mass flow of water of approximately 12,000 lb per second or 90,000 gallons per minute at 1500 lb per square inch.

Taking these values for the temperature differences, and taking a maximum fuel element surface temperature of 576 deg. Fah., the following typical figures are arrived at for the temperatures in the reactor and coolant circuit :

	Temperature, deg. Fah.
Maximum central uranium	786
Maximum fuel element surface	576
Coolant outlet	512
Coolant inlet	476

For the external heat exchanger in this case a steam pressure of 450 lb per square inch and saturation temperature of 456 deg. Fah. may be assumed. The heat transfer diagram is shown in Fig. 7. It is assumed that the feed water is heated to approximately 315 deg. Fah. by bled-steam feed heating before entry to the heat exchanger. The water is thus heated from 315 deg. to 456 deg. Fah. in the main heat exchanger and evaporated at the latter temperature to give a supply of saturated steam at 450 lb per square inch. Taking an average overall heat transfer coefficient of about 800 B.Th.U. per square foot hour deg. Fah., the total surface area required for a heat load of 500MW would be approximately 50,000 square feet.

One possible design for an external heat exchanger is shown in Fig. 8. This diagram refers to a shell and tube heat exchanger arranged as a natural circulation unit. Feed water enters the shell at the bottom and after passing through a feed preheating section it mixes with the boiler circulation water which is returned from the boiler drum. The mixture of steam and water leaves the heat exchanger at the top of the shell and passes to the boiler drum. High-pressure water from the reactor enters the header at the top of the unit and passes downward inside the tubes of the heat exchanger, returning to the reactor by way of the header at the bottom. Another alternative would be to use a horizontal heat exchanger of the shell and tube type with a single fixed tube plate and high-pressure header. The

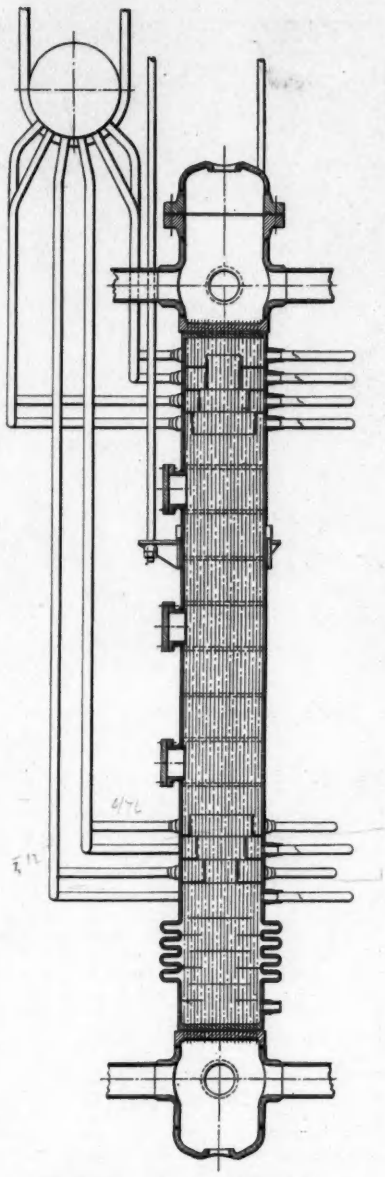
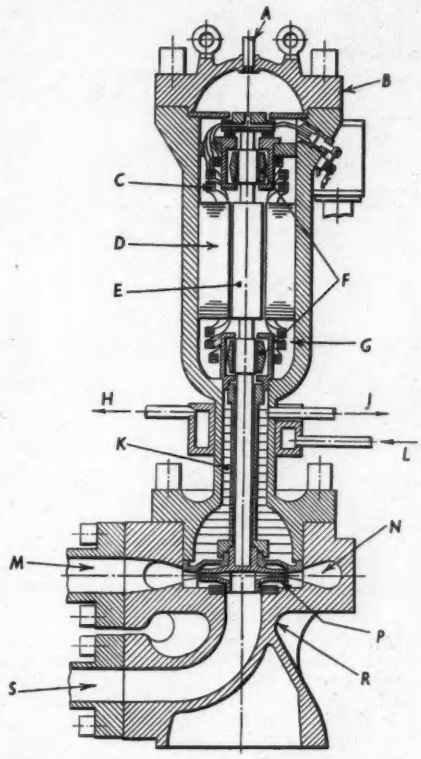


Fig. 8—Vertical steam-raising plant

tube bundle could be made up from hair-pin tubes or, alternatively, straight tubes could be used with a floating header at the other end. Other arrangements for the heat exchanger are also possible, and either natural or forced circulation may be employed.

If the coolant circuit is divided into four parallel branches, the flow in each circuit will be 22,500 gallons per minute to provide for a total heat removal of 500MW, with a coolant temperature range of 36 deg. Fah. Alternatively, six parallel circuits might be employed, each with a flow of 15,000 gallons per minute. Taking the latter case, and assuming a total pumping head of 100ft, the power input to the water required from each pump would be about 360 h.p. and the horsepower required for each driving motor would be about 500. The specific speed of a pump designed for this duty and driven at a speed of 970 r.p.m. would be $N_s=NQ^{\frac{1}{2}}/H^{\frac{3}{4}}=3760$, which is a reasonable value for a single-stage, mixed-flow pump. In view of the high pressure in the primary coolant circuit and to avoid any danger of leakage, it would be desirable to employ a glandless pump with totally enclosed motor drive. One possible type is shown in Fig. 9.

From the point of view of the boiler designer it will be desirable to control the *p*H of the water to an alkaline value between 10 and 11.



A—High-pressure circulation in.
B—Pressure cover.
C—Stator windings.
D—Stator laminations.
E—Rotor.
F—Tilting-pad journal bearings.
G—Pressure shell.
H—Low-pressure cooling-water from jacket.
J—High-pressure circulation out.
K—Heat baffles.
L—Low-pressure cooling-water to jacket.
M—Discharge.
N—V lute.
P—Impeller.
R—Pump case.
S—Suction.

Fig. 9—Glandless circulating pump

It is possible, however, that if any of the normal boiler additives are used trouble may be experienced owing to decomposition under irradiation in the reactor. The possibility must therefore be faced of having to use pure demineralised and deaerated water, which could be extremely corrosive at the temperatures and pressures considered. It may therefore be necessary to employ stainless steel tubes for the heat exchanger and to provide a stainless interior surface to the entire primary coolant circuit. This problem of materials can only finally be settled in the light of operating experience with a complete plant.

Table III—*Comparison of Steam Cycles*

Cycle	*a* Water extraction	*b* High-pressure water reheater	*c* Live steam reheater	*d* Low-pressure superheated steam	*e* Separately superheated steam
Turbine stop-valve pressure, pounds per square inch abs.	420	420	420	210	380
Turbine stop-valve temperature, deg. Fah.	450	450	450	450	900
Reheater inlet pressure, pounds per square inch abs.	—	100	100	—	—
Reheat temperature, deg. Fah.	—	450	400	—	—
Back pressure, pounds per square inch abs.	0·75	0·75	0·75	0·75	0·75
Final feed temperature, deg. Fah.	315	315	315	270	315
Turbo-generator efficiency, per cent	27·8	27·8	27·3	24·3	32·3
Steam rate to turbine, pounds per kW-hour	13·28	11·65	11·84	13·9	9·04
Electrical output, MW	139·0	139·0	136·5	123·0	213
Steam to turbine, pounds per hour	1,850,000	1,620,000	1,620,000	1,705,000	1,850,000
Steam to condenser, pounds per hour	1,140,000	1,140,000	1,140,000	1,188,000	1,368,000
Exhaust area, square feet	139	139	139	145	167

There will certainly be a strong incentive to find a suitable chemical additive for the water which would enable mild steel to be used throughout the coolant circuit.

[Having arrived at the conclusion that, with a reactor pressure of 1500 lb per square inch, saturated steam can be generated under practical conditions at a maximum pressure of about 450 lb per square inch, the authors go on to the question of the choice of steam cycle and the design of the external plant. A number of different arrangements are analysed on the assumption that steam is generated at a normal working pressure of 420 lb per square inch. These schemes are: (*a*) saturated steam with water separation, (*b*) saturated steam with intermediate reheat, (*c*) saturated steam with live steam reheat, (*d*) superheat from the reactor with lowered boiler pressure, (*e*) external superheating from a combustion source. In Table III the results are summarised.]

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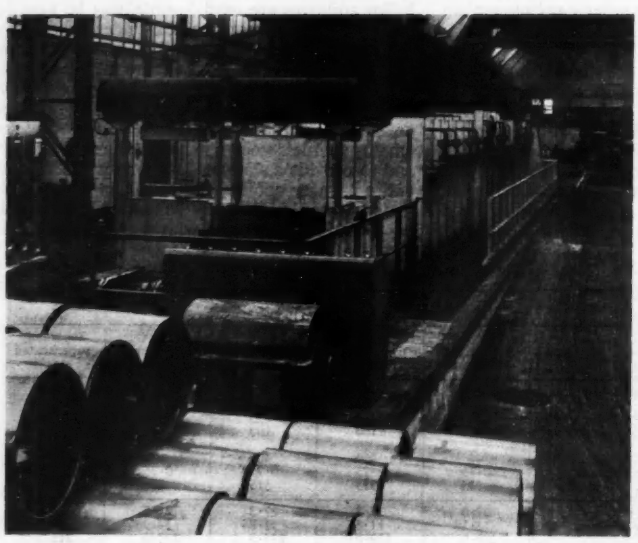
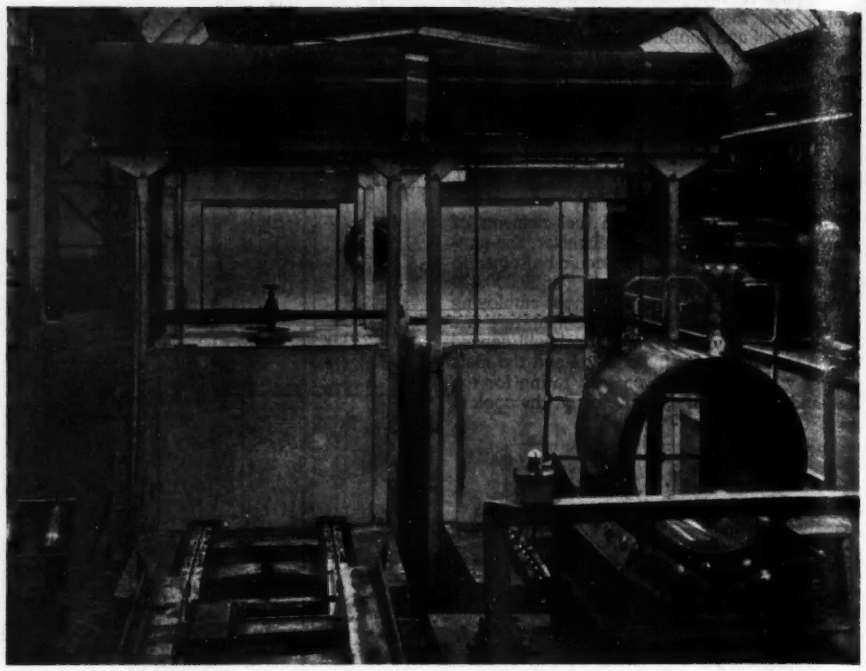
(To be continued)

Heat-Treatment Installation for Coiled Brass Strip

AN electric furnace installation for annealing coiled brass strip and operating on an automatic cycle has been installed in the Witton works of Imperial Chemical Industries, Ltd. (Metal Division), by G.W.B. Furnaces, Ltd., Dudley. In this furnace the coils are moved through the heating zone by a walking beam mechanism. With this mechanism the coils are lifted a few inches above the fixed hearth by beams, which then move forward and drop once more just below the hearth level. The beams then return for the next coil movement cycle. The movement of the beams is arranged to be as near to rectangular as possible, and is effected by two separate motor-driven mechanisms, one for vertical and one for horizontal movement.



50ft long U-shaped annealing furnace for coiled brass strip with inclined delivery conveyor from rolling section at rear



Charging and discharging end of furnace with a coil of brass strip on manipulator after being discharged from furnace and picked up from outgoing conveyor

This method of moving the coils is stated to be better than that using eccentric cams, which tend to subject the charge to abrasive action when it is being lifted from and lowered on to the furnace hearth, particularly in the case of relatively long furnaces, such as that illustrated, in which the total length of moving beam is nearly 50ft.

The furnace is of U shape and comprises an ingoing and an outgoing beam set side by side so that the charge and discharge points are adjacent. Change in travel direction of the charge is effected by a transfer car mechanism inside the furnace at the bottom of the "U." The main heating section of the furnace consists of a twin chamber with a divided central wall, for the purposes of efficient air circulation, the length of this double section being 35ft. The furnace wall, roof and hearth are lined with refractory firebrick backed with graded insulation, while the fixed hearth of the furnace which supports the coils is capped with heat-resisting steel. Nickel-chromium strip heating elements are arranged on the wall faces and roof, while heavy inverted V-section heating elements are fitted in the hearth. To ensure maximum heat transfer from the elements to the charge five centrifugal fans are fitted in the roof on each side of the heating chamber.

A fully bricked and insulated recuperative chamber, which forms a continuation to the double heating chamber, assists in achieving high thermal efficiency, as in it heat is transmitted to the ingoing coils from the outgoing charge. A series of centrifugal fans fitted along the outgoing section of the recuperative chamber assists in heat transfer from the hot to the cold coils. At the charge and discharge points there are short entrance and exit chambers with air locks formed by lifting metal doors. In the exit chamber there are high-pressure water sprays for final cooling of the coils. It is stated that the ingoing coils reach a temperature of approximately 250 deg. Cent. in the recuperation chamber before entering the actual heating chamber; electricity consumption is said to be about 80kWh per ton when heating up to 550 deg. Cent.

The coils being processed weigh approximately 960 lb each and are usually 63/37 or 70/30 brass of about 0·120in or 0·160in gauge, the strip width being 24½in. An output of twelve coils per hour amounting to 5·15 tons per hour is obtained from the furnace, which is designed for a maximum temperature of 850 deg. Cent., while the normal working range lies between 550 deg. and 600 deg. Cent. The rating of 603kW is arranged in nine independently controlled zones and is evenly distributed over the three-phase, 50-cycle supply. An additional 150kW is provided in the bricked section of the ingoing side of the recuperative chamber.

In the operating sequence of the installation coils for heat-treatment are received from the preceding rolling operation down an inclined conveyor. At this stage the coils are in the horizontal position and on reaching a manipulator at the front of the furnace they are up-ended so that the axis is vertical, and set on a short slat conveyor section. On this conveyor they are transferred into the entrance chamber through the atmosphere lock outer door, which then closes. By means of a sequence control mechanism a coil is passed through the inner door of the lock chamber and the ingoing beam then lifts it from the conveyor to start the journey through the furnace. At the bottom end of the furnace a hydraulically operated transfer car moves the coils across on to the outgoing beam. All these movements are effected automatically, and the sequence is then repeated in reverse so that the outgoing beam eventually places each coil in turn on to the conveyor in the discharge chamber. When the exit door opens the manipulator moves across, extracts a coil and turns it back into the horizontal position. The annealed coils are then transferred to a gravity conveyor to await subsequent re-rolling. The object of turning the coils from the horizontal to the vertical position for treatment inside the furnace is to permit the air flow induced by the fans to pass through the centre of the coils

MOTOR INDUSTRY'S SUMMER SCHOOL.—The tenth annual summer school arranged by the Institute of the Motor Industry is to be held from August 25th to September 1st, 1956, at St. Catharine's College, Cambridge.

Locomotives for Heavy Industry*

By C. WORDSWORTH

The locomotive problems of an ordinary factory are entirely different from those of a large steelworks or any other industrial concern of the same magnitude. The steel industry, in particular, is very greatly concerned with efficient and economical motive power and this paper is written around the conditions in one of this country's largest steel plants—i.e. the Steel Division of The Steel Company of Wales, Ltd., at Port Talbot.

General Requirements of any Locomotive

It may be opportune to consider the fundamentals required in any locomotive regardless of the actual type of prime mover.

First, obviously the locomotive must be sufficiently powerful to handle all work normally expected of it. At the same time, careful thought must be given to the future; even if the locomotive is only expected to have a book life of twenty years, much change can take place in this time and in steelworks there is a strong tendency for train weights to be continually increasing. It is, therefore, desirable to see that any new locomotive is more than on top of its job.

Secondly, the locomotive must have sufficient weight both for starting trains and for stopping them. For steelworks use, where high axleloads are permissible, the tendency should be to incorporate plenty of weight so that the locomotive may give of its best under all conditions of rail, even if the sanding gear is out of action, since sand pipes are easily damaged by scrap lying about. The small extra quantity of fuel consumed to move the heavier locomotive is more than justified by the vastly improved traffic performance.

Thirdly, accessibility, both for driver and maintenance staff; although obvious, it is surprising how even now, locomotives are built with very poor accessibility to certain parts and builders do not always realise that there is a vast difference between assembling a new locomotive with clean components and maintaining the same locomotive after it has been in service.

Fourthly, vision from the cab. Until very recently, British builders were notoriously bad in this respect and even now one sees diesel locomotives with small porthole windows in an otherwise empty expanse of cab sheeting. Vision is very important in a works where one may have many level crossings and much road traffic.

With a diesel locomotive there is nothing to prevent a cab from resembling a mobile "greenhouse" and this condition is extremely desirable.

Fifthly, low maintenance costs. Again this is obvious, but even here much could be done to improve the position, both by design and by new materials. There are many examples of modern methods and materials which, although commonly used in general engineering, do not seem to find their way on to locomotives.

Sixthly, the ability to remain in service as long as possible without maintenance or service. Much has been done in this connection in recent locomotive designs. On steam locomotives we find roller bearings, rocking grates, self-cleaning smokeboxes and proper water treatment. With diesels it is perfectly possible to design a shunting locomotive which can remain in service for a fortnight without the driver even needing an oil can.

If this question of diesels is taken further, it would appear that the most important need is to produce a diesel engine which can run for really long periods without any but the most elementary maintenance. Even now, we find certain types of diesel engines in service which, if the engine maker's instruction book was rigidly adhered to, would spend nearly as much time in the shed as on traffic. In general, makers are improving in this respect, but it is felt that there is a very pressing need to increase the period between engine overhauls; it would seem that at least one Continental builder is finding the answer to this problem.

The Conventional Steam Locomotive

The conventional steam shunting locomotive is at the end of its development and, despite all its advantages of low first cost and simplicity, it is uneconomic when compared with other forms of traction. It must be said that little has been done by locomotive builders in the range of their standard industrial locomotives over many years to improve design. These may seem hard words but in the main, special detailing only appears to be done if the customer asks for it, and the customer is seldom a locomotive engineer.

If continued improvements in design and materials had been incorporated over the past twenty to thirty years, then the present changeover to diesel might at least have been delayed.

The author is convinced that it is possible to produce an availability with steam locomotives of modern design that would be the equal of anything normally gained with diesel. The whole thing largely boils down to two alternatives—high capital cost and low running costs with the diesel or low capital cost and high running costs, chiefly due to the price of coal, with steam locomotives. Nevertheless, to get the greatest possible availability out of steam locomotives, it would be necessary to spend a fair sum of money on running shed installations.

The Geared Steam Locomotive

This type of locomotive has been manufactured for a number of years, but it is only in the last few years that the steel industry has taken very much interest in this subject. The chief advantages claimed for this type of locomotive are that it has the high availability and low running costs of the diesel locomotive but at a price very little greater than that of a conventional steam locomotive. These advantages certainly make it appear a tempting proposition.

A new design of this kind of locomotive is now being produced for two of the country's largest steelworks. These locomotives are built to a much heavier design than that normally used and also are interesting inasmuch as they are being built for oil firing and it is understood that this oil firing is to be entirely automatic. It is not proposed in this paper to enter into controversial argument as to whether such a locomotive can be operated at a lower cost than a diesel locomotive, since it would appear that there are many arguments for both sides. Until this latest design of locomotive is put into service and has been operating for several years, it will not be possible for any accurate results to be seen.

The Diesel Locomotive

When a prospective user sets out to buy a diesel locomotive he is faced with a bewildering variety of types, employing different engines and, more important, different transmissions. It is not proposed in this paper to enter into any mention of diesel engine design, since this is a specialised subject in itself. From the users' point of view, it is only necessary to recall the statement previously made, which was that every effort should be made by diesel engine builders to produce an engine which needs a minimum of maintenance over a very long period. Present experience would indicate that by far the greater part of locomotive down-time is spent on routine engine maintenance.

On the question of transmissions, however, he will have to make his choice by himself. The manufacturers of each type will claim certain advantages for it and these may be set out as below.

(*a*) *Diesel Mechanical Transmission.*—This is usually considered to be the cheapest form of transmission. It can be built very robustly and will need little attention in service. The designer will be able to set out his gear ratios to conform with the user's requirements, to ensure that the right power is available for the job at the right speed. The disadvantages of this kind of transmission are noise and inflexibility. Noise can be a source of great annoyance to a shunting crew, since frequently the transmission noise is such that the driver is unable to hear the whistle signals given by the shunter. The inflexibility of a mechanical transmission generally only becomes apparent when working on gradients. Most steelworks have many gradients on their railway systems and changing gear when propelling a train up a grade is frequently a very difficult operation. There are a great number of mechanical transmissions on the market; each one will generally have the advantage over the others in some particular respect and in the most advanced form the transmission may well become almost automatic. This last state, however, is usually gained at the expense of some complication in design, which may give rise to trouble in service.

(*b*) *Diesel Electric Transmission.* — From the operating point of view this is an ideal transmission. It involves extremely simple controls and the stepless tractive effort curve makes it an extremely flexible unit for general duties. It is probably the quietest form of transmission and is popular with operating crews.

From the maintenance point of view it has the disadvantage that two trades of craftsmen are needed for its maintenance. Whereas on other kinds of diesel locomotives an electrician is only occasionally needed for attention to batteries, headlamps, and such items, with diesel electric locomotives the shed staff has to include a considerable number of full-time electricians. However, experience to date would seem to show that a diesel electric locomotive, properly serviced and maintained, only needs major electrical maintenance at long intervals. To support this statement, it may be noted that none of the diesel electric locomotives at the Port Talbot plant have yet had any major electrical maintenance, nor is there any immediate likelihood of that being required. The experience of many users seems to indicate that the major electrical components, i.e. the generators and traction motors, are unlikely to need major stripping for at least eight or nine years. Even then it has frequently been found that the only attention required is skimming of the commutators, and general cleaning.

(*c*) *Hydraulic Transmission.*—The claim for the hydraulic transmission is that it offers the ease of control and the flexibility of the electric transmission but with lower capital cost; it has also been stated that maintenance is almost negligible. Reports from Germany, both from the Federal Railways and industrial users, would indicate that they are more than satisfied with the hydraulic transmission. Until fairly recently this has generally been confined to locomotives of less than 1000 h.p., but recently several large main line designs have been put into service, and statements so far made would indicate that their performance is excellent. As far as this country is concerned, it is too early to be able to draw any firm comparison between shunting locomotives with electric and hydraulic transmission.

It will be seen, therefore, that the three major types of transmission may offer some difficulty to the prospective purchaser. Locomotives employing all three types of transmission are in daily use in various steelworks throughout the country and these locomotives are giving every satisfaction to their users. Nevertheless, it is the author's opinion that the mechanical transmission is not entirely suitable for general steelworks operation for the reasons referred to. These words may appear critical, but experience in the Port Talbot plant has shown that these two disadvantages are very real ones.

Much importance is made by manufacturers about the overall efficiencies of various transmissions. This may be of some importance to main line railways, but from the viewpoint of the industrial user, if he only realised it, this efficiency business really means nothing at all. What he wants is a really robust and reliable locomotive, which will do its work without fuss or breakdown. The fact that one type of locomotive may have a fractionally greater fuel consumption than another is of small importance in the general reckoning.

[The author then went on to deal with experiences with diesel locomotives at Port Talbot, the economics of locomotive operation with steam and diesel traction, maintenance, &c.]

* Paper presented before the Institution of Locomotive Engineers on Wednesday, December 14th. Abstracted.

New Air Services Approved.—The Minister of Transport and Civil Aviation has approved the operation by Silver City Airways of an all-freight service between Lydd, Kent, and Paris, and of Douglas "Dakota" aircraft between Liverpool and the Channel Islands.

LETTERS AND LITERATURE

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

RESILIENCE OF A GYMNASIUM FLOOR

SIR,—Dr. Williams's characteristic letter, which you published on December 16th, makes so much play with "irrelevance" that I may perhaps be forgiven if I restate the question and ask for a simple answer.

Two alternative types of floor which are considered for a school gymnasium are :—

(1) A "resilient" floor of $\frac{7}{8}$in hardwood planking secured to 2in by 2in battens carried on rubber buffers, at about 4ft spacing, which rest on concrete.

(2) A solid floor of granwood or similar blocks which rest on concrete.

In order to get some indication of the resilience of the former we made an experiment. It showed that when a 150 lb boy jumped from 3ft 6in on to a floor of type (1) without a mat the floor at the point of contact yielded 0·03in. The boy's hip came down about 6in after his toes touched the floor. His heels did not touch until after he had again stood erect. For all jump landings a rubber mat containing a 1in thickness of rubber sponge is normally used. The resilience of the floor itself is then of little importance. The experiment described above is not normal practice, but was made for the reason stated.

Children use a gymnasium for periods of forty minutes, of which perhaps twenty minutes are occupied in walking or running.

Will Dr. Williams say in simple terms how much benefit, if any, he thinks that children using a gymnasium in this way would derive from a floor of type (1) as compared with type (2), both floors having equally good surface ?

Perhaps Mr. Muncey would extend his very useful and interesting experiments and analyses to cover the case of running as well as walking, and would say how the resilience of his wood floor compares with that of type (1).

We shall then be able to judge whether it is justifiable to spend an extra £500 on each gymnasium to give it a "resilient" floor of type (1) instead of a "solid" floor of type (2).

T. R. CAVE-BROWNE-CAVE.

Southampton, December 17th.

Literature

Turboblowers. By A. J. STEPANOFF. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 64s.

THIS book deals with the theory and design of compressors (including fans and blowers) of the centrifugal and axial-flow design. Those familiar with the author's book on *Centrifugal and Axial-Flow Pumps* will find that the present volume follows the earlier work very closely both in arrangement and scope. General theory is limited to the discussion of a number of selected topics from fluid mechanics and thermodynamics which bear on compressor design, ranging from the significance of energy gradient in promoting flow through turbo machinery to a long digression on the concept of available energy. The reader is assumed to be familiar with the basic principles of these two subjects at a standard well within that of an engineering degree. Apart from this general theoretical work the early part of the book is devoted chiefly to the consideration of incompressible flow through impellers, with particular reference to centrifugal impellers. Subsequent sections deal with the design of centrifugal blowers, centrifugal fans, axial-flow fans, and multi-stage axial-flow compressors. Separate chapters are included on parasitic losses, cooling, and applications of compressors. A useful list of references is given at the end of each chapter.

The author has clearly set out to apply to this kind of machinery the same methods as are used in the design of hydraulic pumps. A large number of passages are in fact merely reproduced from his earlier book with only minor changes in terminology (such as the substitution of "blower" for "pump"). Calculations are carried out in terms of head and specific speed, and for impeller design a non-dimensional diagram is used, derived from a correlation of test results, and said to be applicable to a complete range of centrifugal and axial-flow pumps and blowers. The experimental evidence for this statement is not given fully in the book, but it may be doubted whether a high degree of accuracy is likely to be achieved over such a wide range of designs, in compressible flow, without the adoption of a more fundamental approach. These methods are in fact discarded when the design of multi-stage axial-flow compressors is considered, and here use is made entirely of British data obtained from published papers by members of the National Gas Turbine Establishment.

The extension of the theory from the incompressible flow case of the author's first book to cover compressible flow has not always been fully thought out, as witness the attempt in Chapter I to define "head" as something independent of the process of compression, an attempt which is tacitly abandoned in Chapter 2, to be replaced by rather confused definitions of adiabatic, polytropic, and isothermal heads and the corresponding efficiencies. The confusion reappears in Chapter 7, where the expression "polytropic compression work" is used for the quantity usually known as the cumulative work, which is equal to the product of polytropic work and polytropic efficiency. There are a number of instances of statements made generally which apply strictly only when the fluid is incompressible. Surprisingly, the well-known method of plotting compressor characteristics non-dimensionally is not given for a compressible fluid.

Generally the book gives the impression of having been put together a little hurriedly. The treatment is often uneven and occasionally includes such questionable statements as "Both pressure energy and heat energy are due to molecular kinetic energy and are interchangeable as is well known in thermodynamics of gases," in addition to slips such as the statement on page 123 that the viscosity of air is higher than that of water. There is a tendency to rely on dogmatic assertions (with the all-too-frequent use of italics) rather than on a logically developed argument, and the reader is often presented with a statement and left to search for the reasons elsewhere in the chapter, or even in subsequent chapters. It is regretted that owing to these weaknesses the book cannot be recommended as an introduction to the subject. But readers more familiar with compressor design will find in it many points of interest.

Mouvement Oscillatoire avec Viscosité et Inertie. By CLAIRE CLARION. Publications Scientifiques et Techniques du Ministère de l'Air, No. 303. Paris : Service de Documentation et d'Information Technique de l'Aeronautique (S.D.I.T.), Magasin C.T.O.: 2, Avenue de la Porte-d'Issy (15e). Price 1000 francs.

THE theoretical study of the motion of real fluids suffers from the fact that even in cases where the equations of motion can be written down with sufficient accuracy to represent the flow characteristics as well as the boundary conditions, these equations cannot in general be integrated. An exception to this rule is found in oscillatory movements, provided they are of small amplitude. Such movements also offer the advantage that their experimental study is easy. This enables a comparison to be made between theory and experiment in a field which is of considerable practical importance, e.g. for the transition between two steady states, such as occurs in the operation of motor and hydraulic controls.

The chief subject of the present monograph is the free movement of a column of liquid. Mlle. Clarion has repeated by means of an improved technique the measurements made by Menneret in 1911 of the period and decay of such a motion. The results are expressed in terms of the non-dimensional parameter R^2w_p/ν and show the existence of two regions of flow. This is confirmed by an examination of the displacement-time curves by means of a novel method due to the author, called the "method of interfaces." The theory developed allows the logarithmic decrement of the motion to be calculated for both regimes, in the case of oscillations of infinitely small amplitude.

In the second part of the report, the case is described of a transient oscillation in a surge shaft after the closing of the penstock valve. The theoretical treatment which is developed to cover this case leads to results which correspond with those obtained from experiments. Lastly, the "method of interfaces" is applied to the case of the transient in a capillary tube before the quasi-stationary flow is established.

Etude Thermique des Ecoulements d'Air Raréfié en Régime Moléculaire Libre. By F. MARCEL DEVIENNE. Paris: Publications Scientifiques et Techniques du Ministère de l'Air. No. N.T.55. Obtainable from Magasin C.T.O., 2 Avenue de la Porte d'Issy, Paris (15e). Price 400 francs.

MEASUREMENTS have been taken of the stagnation temperatures on a small plate exposed to a molecular air stream, i.e. one where the mean free path was great compared with the cross-section of the duct. The flow was obtained by joining two vacuum vessels by a pipe which was long compared to its diameter, and the test surface was placed at its downstream end, at right angles to the mean flow. Temperature measurements were taken by a thermo-couple, due allowance being made for errors from radiation and conduction, and the rise in temperature observed was found to depend upon the speed of flow and the air pressure. An approximate theory is developed on the basis of the kinetic theory

of gases. The results show that in the molecular régime the recovery factor is greater than unity.

Into the Water Barrier. By DONALD CAMPBELL. London: Odhams Press, Ltd., 96, Long Acre, W.C.2. Price 15s.

A LIGHT and readable account of the attempts of "Bluebird" upon the absolute water speed record, resulting in a mean of 202·32 m.p.h. being established in July this year, has now been prepared. The early part of this book by Donald Campbell is mainly autobiographical. After the death of his father, Donald Campbell attempted to raise the existing record with Sir Malcom Campbell's second "Bluebird" boat. But unexpected problems were encountered, particularly a completely unpredicted trim by the nose at high speed. Comparison with the experiences of Stanley Sayers with the "Slo-moshun" craft in the U.S.A. led to new study of the problems involved and a basic change in the design of really high-speed craft. When a new hydroplane was designed to do over 200 m.p.h., a configuration with two planing areas forward and one aft was adopted, together with a jet engine which gave consistent and trouble-free service throughout the attempts. But the boat suffered severely from adverse trim changes and spray entering the air intakes. Even so, it finally achieved a best speed of over 215 m.p.h. Only nine days after this record, the introduction to this book was written by Campbell's collaborator, A. W. Mitchell.

The book is intended for the general lay rather than the technical reader, and what technicalities there are will, we fear, be quite valueless to those without previous knowledge of the subject: Campbell's narrative, for example, refers consistently to a "point of minimum drag," which is never explained. There are also certain irritating geographical and typographical flaws, the result perhaps of hasty preparation for the press. A large selection of photographs is included, but more views of the boats out of the water, showing the nature of a hydroplane, would be valuable to the technical reader. Many of the illustrations are portraits, and the text gives generous acknowledgment to all those who contributed to the speedboat's success.

The Principles of Technical Electricity. Second edition. By M. NELKON, M.Sc. Glasgow: Blackie and Son, Ltd., 17, Stanhope Street, C.4. Price 10s. 6d.

THIS book is intended to cover the requirements of City and Guilds Telecommunications Examinations, Principles I and II. Introductory chapters on d.c. and a.c. theory lead up to a study of the basic principles of diode and triode valves and the cathode-ray tube. An appendix on the M.K.S. system is included in the second edition. Questions at the end of certain chapters have been brought up-to-date by the addition of examples taken from recent examination papers.

Dynamics in Machines. By F. R. ERSKINE CROSSLEY. New York: The Ronald Press Company, 15, East 26th Street. Price 7 dollars.

THIS volume commences with the kinetics of particles and works exhaustively through to a chapter on flexible machine members in motion and on governors. In each section no effort has been spared to present information clearly, drawings and examples being profuse. So complete is the text that an appendix to the chapter on equations of motion gives solutions of various first and second order differential equations, though the promise, in the introduction to the chapter on three-dimensional rotation, of an explanation of the boomerang is not fulfilled. While the text rarely lacks the virtue of simplicity, the mechanisms studied are not so restricted: the balancing of almost every kind of piston engine except the vee-twin is studied. The author has little use for the "rigid body" concept and thus reaches useful conclusions regarding cam followers and rotating discs. The text ends with a description of the C.A.V. hydraulic governor. Each chapter is followed by a graded bibliography and a set of problems, often originating from Cambridge or London Universities, solutions to some being given. It is regretable that the price will deny this volume to the bulk of undergraduates.

The Slide Rule for Students of Science and Engineering. By T. G. C. WARD and G. W. BLAKEY. London: English Universities Press, Ltd., 102, Newgate Street, E.C.1. Price 3s. 6d.

THIS small book treats the theory of the slide rule in an elementary manner, showing, for instance, that the difference of two squares can be found by a process of multiplication. A slide rule is postulated in which the hair line is on the front of the cursor and the trigonometrical scales on the back of the slide. The use of differential scales is not mentioned, but the Log Log scale is referred to in an appendix. The authors believe that "drill" for ten minutes a day is more valuable than two hours a week, and reiterate this throughout the book: they provide answers to the examples to four significant figures. There is no index.

Heat Insulation. William Kenyon and Sons, Ltd., Dukinfield, Cheshire.

AFTER a chapter on the quantitative estimation of heat transfer by conduction, convection, and radiation, for steady temperatures, this book proceeds to discuss the thermal and physical properties of insulation. For problems regarding the economics of insulation a series of theories and examples is given, together with graphs for solving these problems for various sizes of pipes. Insulations ranging from aluminium foil to cork and vermiculite are described and illustrated, and the final chapter deals with the techniques of applying them. A number of widely different equipments are taken as examples, and the application of fire protection to structural steelwork is illustrated.

Escher Wyss 1805–1955: 150 Years of Development. Edited by H. Sitterding.

THE greater part of this book is devoted to tracing the products and methods of Escher Wyss through its history. In the nineteenth century each Swiss factory manufactured the whole of its own requirements and versatility was its pride: thus up to the end of the century Escher Wyss marketed spinning machines, its original production, locomotives, tractors and ships: the illustrations include a steamship and a naptha launch. The later history, while having as its keynote turbo-machinery, includes such applications as refrigeration. It is shown how the Francis and Kaplan turbines developed, and led to the manufacture of reversible air-screws and a variable-pitch propeller for a 10,000-ton freighter. The heat engines likewise range through Zoelly turbines to closed cycle gas turbines utilising the compact combined turbine-compressor construction. A particularly interesting section is devoted to the research work on hydrodynamics and physical problems, and another to the testing of materials. The photographs are consistently excellent, and many would be valuable in text books. The text of the English version, however, bears the marks of a translation.

Book of Reference

Rules and Regulations for the Construction and Classification of Steel Ships. 1955. Lloyd's Register of Shipping, Garrett House, Manor Royal, Crawley, Sussex. Price 42s.—The book sets forth the general rules and regulations of Lloyd's Register of Shipping, the classification regulations and the periodical survey regulations before dealing with the construction rules. These are concerned with the determination of scantlings, assignment of class, material, method of construction, distribution of material and the definitions of dimensions used in the rules. Separate sections, with which are associated tables of scantlings, give the rules dealing with particular parts of the ship's structure. There are chapters dealing with pumping and piping, fire-extinguishing arrangements, steam main and auxiliary machinery, boilers and electric propelling machinery and equipment. Other chapters are concerned with refrigerated cargo installations and the quality and testing of materials.

Technical Reports

The Dispersion Meter. Design and Development (Ref. V/T121). By G. Mole, Ph.D., F.Inst.P. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 18s., postage 4d.—Measurement of dielectric dispersion (i.e. the relative increase in instantaneous capacitance) over the time range 3—300 msec has been found to be a useful method of testing paper insulation, since it is sensitive to significant quantities of moisture and yields zero response for dry specimens. This report covers the design and development of a portable electronic instrument which measures directly the dispersion and leakage-time-constant of insulation of all kinds within the capacitance range of 70 pF to 0·35 μF, and gives readings which are immediately significant. Detailed instructions for calibrating and using the instrument are given in a companion report (Ref. V/T124), price 10s. 6d., postage 3d.

Flight Tests at Transonic Speeds on Freely Falling Models, Parts I to V. Edited by C. Kell. H.M. Stationery Office. Price 8s. 6d.—This report covers an early technique for testing aerofoils through the transonic range of speeds, in which bodies released from an aircraft at height accelerated by gravity through these speeds. Radar recorded the flight path and telemetering equipment transmitted information to a ground station during the fall. Part I is a historical précis of the work, which was started in 1943 and brought to a close in 1949, and Part II describes the technique and the models. Drag measurements on nine wings are presented in Part III, and the application to flutter is considered in Part IV. Part V discusses the accuracy of the technique, the limited accuracy of the telemetering equipment being the main reason for abandoning the experiments.

The Machine Boring of Wood. Forest Products Research Bulletin No. 35. H.M. Stationery Office. Price 2s. 6d.—In wood boring operations, the power demand and quality of the finish produced depend on the shape and dimensions of the bit, the machine feed speed and cutting speed. The report describes tests carried out on various species of hardwood and softwood, to determine the relationship of these factors and their effect on the service life of the tool. The influence of growth characteristics and grain orientation of the wood on the results is also discussed.

Books Received

Technical Education. By P. F. R. Venables. London: G. Bell and Sons, Ltd., York House, Portugal Street, W.C.2. Price 42s.

The Papers of William Froude, M.A., LL.D., F.R.S. London: Institution of Naval Architects, 10, Upper Belgrave Street, S.W.1. Price 84s.

Applied Electricity. Fourth edition. By H. Cotton. London: Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, W.8. Price 20s.

Strength of Materials. Second edition. By B. B. Low. London: Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, W.1. Price 18s. 6d.

Tables of the Cumulative Binomial Probability Distribution. London: Oxford University Press, Amen House, Warwick Square, E.C.4. Price 63s.

Power System Plant. Edited by E. Openshaw Taylor. London: George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 30s.

Concrete Materials and Practice. Second Edition. By L. J. Murdock. London: Edward Arnold (Publishers), Ltd., 41, Maddox Street, W.1. Price 40s.

Modern Clocks, Their Repairs and Maintenance. Third Edition. By T. R. Robinson, London: N.A.G. Press, Ltd., 226, Latymer Court, Hammersmith, W.6. Price 30s.

Nuclear Power Reactors

INSTITUTION OF MECHANICAL ENGINEERS

On page 902 of this issue we reprint extracts from a paper entitled "The Pressurised Water Reactor," presented before a meeting of the Institution of Mechanical Engineers in conjunction with the British Nuclear Energy Conference on Wednesday, December 14th. Below is printed an abstract of the ensuing discussion.

MR. R. V. MOORE, G.C.: Considerable attention is being directed to the development of a pressurised water nuclear power plant both in the British Commonwealth—that is, in the United Kingdom and Canada—and also in the United States of America. In the U.S.A a pressurised light-water reactor is actually under construction, and is no doubt a close relative of the propulsion unit developed for the submarine "Nautilus." It will go into commission about a year after our own Calder Hall plant. In America also a small-scale experimental boiling reactor has been built. In heterogeneous reactors in which the fuel is in some solid form and in which the heat produced in the reactor is conveyed out of the core to the steam-raising plant by a forced convection process, this heat transference may be accomplished currently in one of three ways—(i) by pressurised gas, (ii) by liquid metals, and (iii) by pressurised water. None of these methods is ideal. Perhaps the two major shortcomings of the pressurised water method are the following. First, although water is considered normally to be a non-corrosive agent, at high temperatures it is just the reverse ; in particular, its attack on uranium metal is violent. Secondly, at atmospheric pressure it boils, of course, at 100 deg. Cent., and the effect of this on the design of the plant is shown by the input to the turbines being low-pressure saturated steam. Water, while being generally an excellent low-temperature coolant, has many shortcomings for high-temperature applications. The authors have set themselves a very difficult task in surveying a potentially important type of nuclear power plant in one paper, and, in writing it from the aspect of the power plant engineer, perhaps the problem of core design, which is where 80 to 90 per cent of the research and design problems are concentrated, is somewhat under-emphasised.

One effect of this approach is, I think, that the heat output of the reactor postulated in the paper is somewhat inflated, for a number of reasons. This can be somewhat glibly substantiated by saying that the American reactor which is under construction, and which is a pressure vessel 9ft in diameter, pressurised to 2000 lb per square inch—a very similar design to the one in the paper—has a reactor output of 290MW and 85MW electric power as target figures, which are considerably less than the 500MW and 130MW of electric power referred to in the paper. This will, of course, have an adverse effect on the economic assessment of the plant. At this stage of development, however, I think that it is fruitless to compare alternative plants on an estimated economic basis, since the cost per unit with each alternative lies somewhere between ½d. and 1d. per unit, and is obviously related to some basic law arising from the fact that we are raising and utilising comparable quantities of heat at round about the same temperature. It is unlikely, therefore, that this approach will enable us at this stage to select types of reactor for further development. Comparisons must be on a more subtle and detailed basis than this.

I have said that 80 to 90 per cent of the research and design effort is centred on the reactor core. It is possible to segregate four major groups of problems : (i) the fuel element design and performance ; (ii) the heat rate of the reactor of specific size ; (iii) the neutron economy of the core, and (iv) the accommodation of operational requirements, and particularly (*a*) arrangements for loading and unloading the fuel, (*b*) the control of the reactor in the steady state and in the transient states associated both with normal load changing and fault conditions, and (*c*) the detection, localisation and methods of dealing with fuel elements which have become faulty. These factors are completely interlocking, and what is essential in reactor design is to strike the right balance, to find the right simultaneous solution for all these problems. As an example of this, in the paper it is quite rightly suggested that ½in diameter uranium rods would be advantageous from the point of view of obtaining a high fuel rating. If, however, the design is being looked at from the point of view of neutron economy, it would be beneficial to use 1in diameter rods with a consequent reduction in fuel rating. This may be one of the reasons why the heat output postulated in the paper seems to be on the high side. I would interject here the thought that when designing with enriched fuel it is a misconception to think that neutron economy becomes less important. It may be less critical, but the effects of poor neutron economy will always appear in the final answer and must be offset by another factor, such as reduction in the capital cost of the plant.

The highly corrosive properties of high-temperature water on uranium constitute a major embarrassment to the successful development of a satisfactory fuel element. Alloys of uranium which are more resistant to attack have been found, but they are expensive in neutrons and seem to detract from the ability of the fuel to withstand radiation damage. It is interesting to note that, in the pressurised water reactor which is under construction at Shippingport, the Americans are using uranium oxide as the fuel, the core having a circumferential zone of zirconium fuel elements in which almost pure fissile material is uniformly dispersed. This fuel element behaves basically as zirconium. The uranium oxide, of course, has a much lower density than the metal and is difficult to process after irradiation, while the zirconium fuel elements must be very expensive, so that a price has to be paid for using this type of fuel element which must be quite substantial.

Plant capital costs per kilowatt sent out are always reduced by increasing the rating of the fuel, with the subsequent reduction in reactor size for a given output. Some 20 per cent of the capital cost of the plant can be affected in this way. If this increase in rating, however, can be achieved by an increase in the maximum temperature of the system, this reduction in capital cost extends to the steam plant as well as to the reactor, and a much larger proportion of the capital cost will be affected. There seems little prospect of achieving this in pressurised water plants. It is perhaps ironical that zirconium, a metal with a low capture cross section and a melting point of 1900 deg. Cent., must be introduced into pressurised water plants to resist the corrosion effects, and yet there appears to be little chance of using its high melting point to raise the maximum operating temperature of the system.

The neutron economy of a practical light-water system does not permit the use of natural uranium as fuel ; to achieve this it would be necessary to use heavy water, or D_2O. If we look at the implications of this on a full scale, it may be said that in the early 1970s—by which time virtually all the new generating capacity in the United Kingdom may be met by the construction of nuclear power stations—the annual rate of installation of new capacity may be increased to 3000MW. The capital cost of building a large D_2O production plant, given present techniques, is believed to be about £70 per pound per year. The adoption of a D_2O reactor as the standard commercial reactor would therefore imply a large production programme, since about 1 ton of D_2O is required for each megawatt of electrical capacity installed. This would mean that by 1965–70 a D_2O plant of 2000 to 3000 tons per year capacity would be needed, and the capital investment which this would involve would be some £300 million to £450 million. However cynical one may feel about forward planning, these figures are so large as to require very careful reflection.

Time will not permit me to comment on the fourth factor affecting core design, but I should like to emphasise the importance of a satisfactory method of dealing with fuel elements which have become faulty. A solution of this problem is proving rather elusive with water reactors. It is, of course, particularly important in boiling cycles where the reactor coolant is the working fluid.

With the boiling cycles we come to the frontiers of our present knowledge on pressurised water plants. Although many of the problems in core design, some of which I have already mentioned, are intensified, such as the corrosion problems relating to the fuel elements, the problem of steam-water separation, the wide range of reactivity changes associated with changes in moderator density, and a worsening of the neutron economy, this cycle is of great interest because it reduces the scale of the reactor pressure-vessel problem. It is necessary, however, to qualify this statement, and we may do this by taking an example from the paper. It appears at the present time that the rating of light-water boiling reactors may be limited by the space restrictions in the core arising from the nuclear physical requirements. A rating of 40kW per litre may be just possible, in which case a 500MW reactor will require a core diameter of 13¾ft, which, at the recommended pressure of 900 lb per square inch, means a pressure-vessel thickness of 6½in. This cannot be regarded as an easing of this particular problem. Analysis seems to show that for reactor heat outputs above about 250MW it would be necessary to employ heavy water, not primarily to improve the neutron economy, but to obtain wider spacing of the fuel elements to give reasonable fuel ratings.

It is a very noteworthy fact that the first paper to be presented to the British Nuclear Energy Conference should be from someone outside the Atomic Energy Authority. This is highly commendable, and we all hope that it will continue in the future.

Mr. D. R. Griffiths : The authors have made a very strong case for water-moderated

reactors of one kind or another, and, having read their paper, one is apt to ask " Why is not the United Kingdom building pressurised water reactors instead of those obsolete gas-cooled, graphite-moderated ones ? Their efficiency is higher, their capital cost is lower, and it would appear that they can produce power at a very much lower cost." One might also very well ask, if these water-cooled reactors are so simple to design, what the team engaged on this work at Harwell has been doing in the past two years. I am not going to attempt to defend the United Kingdom Atomic Energy Authority's industrial policy here—others are more capable of doing this—but I should like to make one or two comments in connection with this second question.

Most of the difficulties associated with pressurised water reactors, as with most other types, lie with the core design and not with the external plant. We at Harwell have approached the core design problem somewhat differently from the authors, and as a result have been faced with some rather difficult problems, requiring a good deal of experimental and development work. A clue to the authors' line of approach is given in the concluding section of the paper, where it is stated " The real criterion as to whether one type of nuclear reactor is better than another will be reliability and convenience of operation rather than efficiency or even the cost of the plant." While not wishing to under-estimate the importance of these two factors, we believe that the real criterion is the true average cost of useful power produced over the life of the station, and in the true cost reliability and availability are taken into account, as these are reflected in the amount of spare plant which must be installed to cover outages. These are, however, only two factors which enter into the cost ; another very real and important one is fuel cost, which is affected by both thermodynamc and nuclear efficiency. It is in attempting to obtain high nuclear efficiency—in other words, a high conversion factor consistent with low fuel enrichment—that most of our difficulties arise.

Unfortunately, in their illustration of a 500MW core design the authors completely ignore the nuclear aspect. While as engineers we should like to design reactors in this way, and while it may be all right for small experimental reactors, we cannot afford to do so with large power reactors, or at least not until such time as the values of nuclear fuel and fissile material fall considerably below what they are at present. The Russian pressurised water reactor is undoubtedly a sound engineering job, and presumably reliable, but, as it requires uranium of sevenfold enrichment and has a conversion factor of only 0·3, it could never produce power at a reasonable cost and could not therefore be considered a good power reactor. Likewise, from a purely engineering point of view and from an operating point of view the suggested design has a good deal to commend it, but unfortunately it is not a good one if fuel costs are a consideration. The economics given in the Appendix do not, of course, relate to such a core. With ¼in diameter rods sheathed in stainless steel, $^1/_{32}$in thick, plus additional structural material in the form of coolant tubes, &c., the calculated enrichment for such a core, based on a certain amount of experimental work, is at least twice the U_{235} concentration as in natural uranium and the conversion factor on a plutonium recycling basis with non-alloyed fuel elements is less than 0·65. This makes no allowance for flux flattening, but with more or less ideal flattening, as suggested, and the use of alloying materials to make the fuel elements resistant to water corrosion in the event of a can failure, the enrichment factor would be much higher and the conversion factor appreciably lower, possibly 2·5 and 0·6 respectively.

Now, although the differences in these factors from those assumed are sufficient to alter completely the economics presented in the paper, it might be mentioned here that, with suitable core design and progress in other fields of development, e.g. fuel element processing, we are fairly confident at Harwell that generation costs from such reactors could be brought down to a figure approaching that given. To achieve a reasonable conversion factor with low fuel enrichment we are forced to use much larger fuel elements than we should like to do from heat transfer considerations. The core must also be designed for low parasitic absorption and low neutron leakage and, with the comparatively small diameter fuel rods which are necessary for high specific ratings, stainless steel sheathing of the thickness suggested and complete flattening of the radial flux could not be seriously considered. Some degree of flattening may be justifiable, but if no flattening whatsoever were assumed the heat ratings, fluxes and stresses given in Table I of the paper would be up by a factor of 2. Parasitic absorption can be reduced by the use of such materials as Zircaloy 2 instead of stainless steel, but this introduces additional problems, particularly in the fabrication and support of the fuel elements, because of the large difference in the coefficient of expansion between this alloy and uranium. Neutron leakage can be reduced by spiking, as in the case of the American pressurised water reactor, but this introduces peaks in the flux curve, which is just what the authors have tried to avoid, and thereby considerably complicates the cooling problem.

With a variation in the radial flux the fuel elements would have to be discharged in zones (instead of the whole core being replaced more or less as a unit once every twelve months, as could be visualised with perfect flattening), and with the possibility of fuel element failure it is necessary to design the charge-discharge mechanism to operate preferably while the reactor is working, or at least while hot and under pressure. The development of suitable burst slug detection gear is not a simple task and the problem of controlling reactivity changes that occur between the cold unpoisoned state and the hot poisoned condition is also a formidable one, primarily because of the large change in moderator density. It has been estimated that for a reactor of this type approximately 1,000,000 square centimetres of black absorber would be required to control this change in an orthodox core, if control is to be effected by absorbing plates or rods. The design of a suitable core, with closely pitched fuel elements, to accommodate this amount of movable absorber is no mean task. Control by means of movable bundles of fuel elements is another possibility, but this also has its share of problems. These are just a few of the problems associated with the design of a suitable core when it is necessary to consider the nuclear aspect which at the present time, in view of high nuclear fuel costs, cannot be ignored, and these are the types of problem that have been and are being considered at Harwell.

In the estimates for boiling reactors the authors assume that the capital cost per kilowatt and fuel cost per kilowatt-hour vary inversely as the efficiency. From the figures presented one would immediately conclude that boiling reactors will produce power at a lower cost than non-boilers. This is erroneous. It is generally agreed that the heat output obtainable from a given size of core under boiling conditions is very much less than under non-boiling conditions, because of such considerations as fuel element burn-out, moderator density variations, hydraulic stability, &c., so that for a given output an appreciably larger core would be necessary in the boiling case. Add to this the extra cost associated with reactivity control, corrosion control, steam and water separation, the use of radioactive steam and feed, and a boiling reactor could reasonably be expected to cost more per kilowatt than a non-boiler, despite the fact that heat exchangers are no longer necessary. The higher thermodynamic efficiency achievable with a boiler would be partly, if not wholly, offset by the decreased nuclear efficiency. Furthermore, in the event of fuel element failures, some fission products, particularly the gaseous ones (which usually decay to solids), are certain to be carried over with the steam and deposited throughout the plant, and plant maintenance, because of this, is bound to be higher and availability lower. The answers to all these problems are not yet known, but it should not be regarded as a foregone conclusion that a boiling reactor is a better proposition than a non-boiler. The gains to be obtained by boiling, if any, are unlikely to be very great.

Regarding the various steam cycles considered, I think that we have given due consideration to the various alternative possibilities, and our present feelings are that if a pressurised water reactor were proceeded with in this country it should be coupled to a separate oil-fired superheater, not necessarily because of the higher efficiency obtainable, but because it would enable more or less standard turbine plant to be used. In the comparison of superheated and saturated cycles, it might first be pointed out that the overall efficiencies given in the paper are actual generating efficiencies, no allowance having been made for auxiliary power requirements. On a " sent-out " basis these efficiencies would fall to about 25 to 30 per cent respectively. However, there is no denying the fact that a considerable gain in efficiency is possible by the adoption of a separately fired superheater, but whether or not it pays to superheat depends on the relative cost of nuclear and fossil fuels. This problem has been examined at Harwell on the assumption of high load factor operation, and briefly the conclusions reached were that on present United Kingdom plant and fuel costs it would pay a large generating system such as the C.E.A., having virtually no limit to the unit size of plant that can be connected to its networks, to build as large a reactor as economically possible and to increase the output and cycle efficiency by the addition of a separate superheater. The position could change, however, in view of rising coal prices and lowering nuclear fuel costs. For smaller systems, where the maximum permissible output from a single unit can be obtained from a reactor turbine set operating on saturated steam (say, about 100MW), it would not pay to use a smaller reactor combined with a superheater to give the same total maximum net output. Turbine manufacturers, with an eye on the export market, might profitably devote some effort to the development of saturated steam turbines, if pressurised water reactors are proceeded with.

My only other comment is that most of the efficiencies given in the paper are theoretical generating efficiencies, no allowance being made for auxiliary power. The auxiliary power for all highly rated water reactors is fairly high, and the important figure is the

overall efficiency on a sent-out basis. However, it is realised that without detailed designs on which to base estimates of pumping losses, &c., any figures given would only be very approximate at the best. In this connection, it might be pointed out that the estimated pumping power given for a pressurised water reactor is, in our opinion, very low and should have been based on a total drop of 100 lb per square inch rather than 100ft head. This would make the coolant pumping power about 7½MW, which, on a megawatt heat basis is about the same as the American pressurised water reactor and our own estimates for a similar type of reactor.

Dr. A. B. McIntosh : The authors have dealt with the feasibility of the pressurised water reactor from a steam-power standpoint and one of their objects has been to make a case for the research and development work needed to solve the metallurgical problems. Unfortunately they have not stated what these problems are and, therefore, their magnitude and difficulty may escape notice. Some of the problems may be considered in relation to the essential parts of the reactor. First of all there is the pressure vessel of mild steel. The authors speak in terms of 7½in wall thickness fabricated to 9ft or 10ft in diameter in welded construction and approximately 40ft in height. It should be noted that no steelmaker would guarantee to make homogeneous plate to such thickness. Because of the thickness, the size of the plate would have to be reduced, resulting in an increase in welding difficulties. The welding of such thicknesses and the inspection of the welding to ensure a standard compatible with the hazards involved will present the greatest difficulty. If a stainless steel were chosen there is as yet no technique available in this country capable of ensuring sound welds in such thicknesses of stainless steel plate or of ensuring proper standards of fault detection. The selection of the material from which the shell will be made must be viewed against the conditions which can allow of the evolution of atomic hydrogen. Under such conditions this would diffuse into the pressure shell material. If this is mild steel there would be reaction with carbides, possibly forming methane, and in the worst cases methane blisters would result and intergranular separation may take place. We can safeguard against this sort of thing by the use of an alloy steel such as chromium steel, but as soon as we do that we introduce almost insuperable welding problems in view of the thickness of the plate. The use of a clad steel has been mooted, but clad steels have their own difficulties. We should still have diffusion of atomic hydrogen with the possibility of blister formation at any discontinuity between the cladding and the plate. If we consider a cladding which is of stainless steel, or a plate of stainless steel, we come to another very serious problem which we have found in the laboratories of the Materials Group of the A.E.A., and that is the stress corrosion cracking of stainless steel by demineralised and deoxygenated water. We feel that this is particularly likely to occur when we have the probability of alternate wet and dry conditions. We also feel that the possibility of this stress-corrosion cracking may be more serious than our evidence suggests at the moment.

With regard to the fuel elements, the difficulties of selecting materials for fuel elements entirely depend on the extremely corrosive nature of the pressurised fuel, water. No satisfactory material is at present available. At various times stainless steel, zirconium alloys and aluminium alloys have been considered. With stainless steel there is the problem of stress corrosion, but no doubt this could be eliminated by suitable design. In the conditions of irradiation there may be substantial and persisting dimensional changes of the fuel. The introduction of stress-corrosion conditions arising from this source must also be considered. With alternative canning alloys such as zirconium alloys or aluminium alloys dangers may arise from pitting corrosion or from metallurgical defects ; but whether pitting corrosion or stress corrosion occurs the effect would be the same ; there would be intense corrosion of the uranium fuel with a rapid release of fission products accompanied by pressure increase due to hydrogen evolution. This brings into this type of reactor a hazard potentiality which seriously affects the assessment of its feasibility. The obvious way to reduce such hazard is by the use of corrosion-resistant alloys. Alloys containing percentages of molybdenum and niobium have been studied. Alternatively, we can use or consider non-metallic oxides of low reactivity. With either an alloy or an oxide we must increase the enrichment. To date, however, corrosion-resistant fuels have given this result, that corrosion may be delayed for an induction period, but at the end of that induction period corrosion will take place catastrophically. This leads to another difficulty, because, due to the fact that corrosion is delayed and has been reduced, the difficulty of first detection is considerable. A further consequence of the use of an alloy fuel, or of the use of an alloy can, perhaps bonded to a fuel, is that we may make the recovery process for plutonium one of great difficulty in the chemical processing. All of these troubles can be reduced if the temperature of the pressurised reactor is reduced and the reactor is used as a plutonium producer only. This has obviously no attraction for steam power engineering and, even though the problems are successfully overcome, there will still remain the principal hazard, which will be the catastrophic effect on the corrosion of the fuel by pressurised water. This may lead to considerations of containment of the reactor which will seriously diminish its attractiveness.

Professor J. Diamond : By appealing mainly to thermodynamic and cost considerations, the authors have described the characteristics of a pressurised water reactor and a sub-type, the flash-steam reactor. They do not seem to be so enamoured of the boiling-water reactor at present, but they conclude by saying that reliability and convenience of operation rather than efficiency or even cost are the real criteria in the choice of a type. We must all agree that the qualities of reliability and convenience of operation are essential, but I suggest that it might be better to say that, given reliability and convenience of operation, the cost of the power produced is the real criterion of whether one type is better than another. One of the advantages given by the authors for the flash-steam reactor is that it may operate at a lower pressure than the pressurised water reactor. Indeed, the operation of the former depends on the water temperature from the outlet being close to the maximum fuel element surface temperature. In the examples given in the paper, the pressure in the pressurised water reactor is high enough for the saturation temperature to be in excess of the maximum fuel temperature, whereas in the flash-steam reactor the reverse is the case. If safe operation can be assured for the flash-steam reactor under these conditions, could not the same conditions be applied to the pressurised water reactor, thus simplifying the problem of designing the pressure vessel?

Mr. R. H. Burdett : The authors have shown that thermodynamically the separately-fired superheater is an attractive idea, and have also referred to the increased complexity of the siting problem. This type of scheme might prove to be justified in specific instances, but in general it must be remembered that, in this small and heavily populated island, sites for any kind of power station are not plentiful. In their paper to the Inaugural Session, Messrs. Pask and Duckworth showed that the capacity of coal-fired plant might well have to be doubled between now and 1980. As a result of this, it may be that the extreme shortage of sites will force the C.E.A. to take advantage of such freedom of siting as nuclear power permits and place the nuclear plants at places where supplies of fossil fuel would be extremely difficult to arrange.

If we consider a table in the paper and assume four such separately-fired superheated units on a site, the combustion heat would amount to 652·8MW. At an overall efficiency of 33 per cent, which is appropriate to modern coal-fired plant, the superheater installation would be equivalent to 215MW of conventional plant, as far as coal and ash handling facilities are concerned. This serves to show that the latter problems would not be insignificant. From these purely practical considerations, then, a reactor unit which is competitive without recourse to separately-fired superheaters has an advantage.

Mr. R. Allard: The authors come to the conclusion that with both the pressurised water and boiling-water reactors some type of forced circulation is necessary. This means that for the safety of the reactor the maintenance of this circulation is essential. I should have liked to see some treatment of this subject, in that in the boiling-water reactor shown the water circulation is obviously affected by variations in steam pressure in a way in which the pressurised water reactor is not. Since safety is likely to be an important matter in these first water reactors which are to be built, I should be very interested to hear the authors' views on the inherent stability of the pressurised water reactor as compared with the boiling-water reactor.

Mr. T. R. Warren : As a visitor I very much welcome this opportunity of listening to the paper and saying a few words in the discussion. A study of the paper leaves the impression that the pressurised water reactor using light water offers very few advantages over the more orthodox graphite-moderated gas-cooled type. One of the advantages of the pressurised water reactor, however, is that it makes no demands on the limited supply of special graphite, which will be in great demand when the accelerated programme of nuclear power development gets under way. As against this, however, the use of light water as a moderator involves the use of enriched uranium, whereas the graphite moderator enables natural uranium to be employed. Any large-scale adoption, therefore, of this type of reactor would require large quantities of plutonium for enrichment of the fuel, and we must therefore ask ourselves how this plutonium is to be obtained. It does not occur in nature, and if we were to absorb the supplies used in our graphite-moderated reactors, the time when it would be possible to construct breeder reactor plant on a large scale would be considerably delayed.

The graphite-moderated reactor has, in my view rightly, been chosen to pave the way to more advanced designs. The plutonium can be separated by chemical means from the irradiated fuel and stored for later

use in the breeder reactor. The fuel replacement is then effected by means of natural uranium, and I gather that the cost of this is of the same order as the value of the product recovered. The process is rather like the extraction of honey from the hive and its replacement by ordinary sugar.

As the nuclear power programme develops, it will be necessary for the supply industry to look for more load to keep the plants in full operation during the night. There is relatively little pumped storage in England, although we are more fortunately situated in Scotland. A suitable outlet might be found in the large-scale hydrolysis of water for heavy water concentration, and the hydrogen produced in this way could be used for steam superheating. Sufficient hydrogen could be stored each day to permit the electrolytic plant being shut down during peak-load periods. If nuclear energy fuel costs are sufficiently low—and there is evidence that they will be—it is possible that a dual-purpose system of this kind might provide supplies of heavy water at a price which would make the heavy water reactor a more attractive proposition than it is at present.

British Nuclear Energy Conference.—In our report in our issue of December 9th, there appeared an unfortunate error. We quoted Sir Christopher Hinton as saying that one of the objects of the British Nuclear Energy Conference was to arrange for the printing and publication of papers in the *Journal of Nuclear Energy*. It is, in fact, of course, in the *Journal of the British Nuclear Energy Conference* that papers will be published; and it was to that Journal that Sir Christopher referred. The mistake was wholly ours and our apologies are due to Sir Christopher, to the Conference and to readers.

Automatic Pressure Butt-Welding Process for High Pressure Pipe Lines*

A brief outline is given here of the Burton automatic pressure butt-welding process for high-pressure pipelines. It is a gas welding process in which the desired pressure is developed automatically by making use of the plasticity of the steel that is being welded to control the welding cycle. The process was originated by Mr. J. E. Burton, a Dockyard Technical Officer, and the initial development work was done at H.M. Dockyard, Rosyth.

THE Burton pressure butt-welding process, which is briefly described and illustrated here, was initially developed to overcome production bottlenecks in quality pipe welding. It employs the novel principle of allowing the plasticity of the steel being welded to control its own welding cycle. Work on this process was started in 1947 at H.M. Dockyard, Rosyth, and later at the Central Metallurgical Laboratory, Emsworth, and H.M. Dockyard, Portsmouth.

Essentially the process consists of bringing the faces to be joined together under a minor load and heating them by means of a multi-jet oxy-acetylene oscillating ring burner until a preset thermal expansion is reached. A second, higher load (or control load) is then applied to return the pipe to its original length, when the final butting pressure operates to complete the weld. All sequences are controlled automatically by limit switches which are also arranged to control upset and to cut off the gas supply just before completion of the weld.

Schematically the system of control is shown in Fig. 3. It will be noticed that the welding operation is controlled by a rod, carrying the limit switches, locked to the moving part of the machine, which, by recording linear dimensional changes, causes the welding sequence to occur. Welding temperatures are not measured, but may be systematically varied by alteration of the control pressure; raising the pressure reduces weld temperature and lowering the pressure increases weld temperature. Working pressure limits for the production of satisfactory welds are generous and welding times lie between forty-five seconds and four minutes, according to pipe wall thickness.

Two practical machines using these principles have been constructed; one is for shop use and the other is a prototype portable model. The development of the portable machine was undertaken because of the particular advantages foreseen in the application of this process to the welding of pipes on site and in positions of limited access. The "shop" model can be adapted as a transportable machine.

The Portsmouth "shop" machine is shown in Fig. 1. By the use of different size ring burners and collet holders it is capable of welding pipe-to-pipe and pipe-to-flange in sizes from 3in O.D. to 8in O.D. for wall thicknesses between $\frac{1}{16}$in and $\frac{1}{4}$in. Provision has also been made for tube turn to pipe and tube turn to flange welds.

The portable machine for pipes of 1½in to 2½in O.D. and ¼in wall thickness is shown in Fig. 2, and consists of three separate units—the welding head, the hydraulic cabinet and the connecting leads. The design is such that the welding head may be assembled round the pipe in any position.

In both machines an oxy-acetylene flame on the reducing side of neutral is used and commercial flow meters and a back flash arrester are fitted in the gas supply, which is by manifold cylinders of oxygen and acetylene. Burn back arresters are fitted direct to each half of the ring burners. Joint preparation consists of a fine machined bevel finish with mating faces on the bore of the pipe. Weld upset is controlled to be between 50 and 60 per cent, and no subsequent machining of inside or outside reinforcement is required as significant edge weaknesses are absent. A macrosection of a completed 8in diameter pipe-to-pipe weld illustrating grain flow is shown in

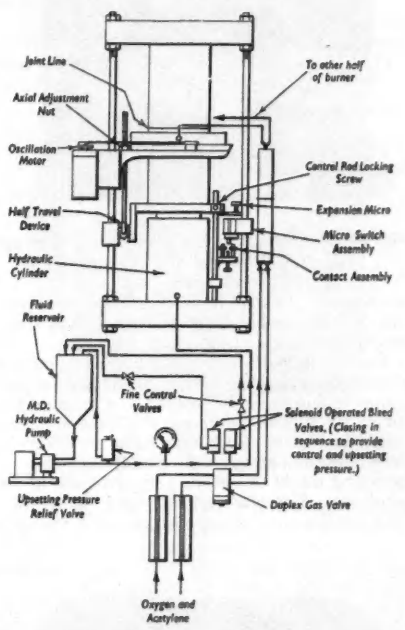


Fig. 3—Schematic diagram showing system of control of pressure butt-welding machine

* Admiralty Bulletin No. 73.

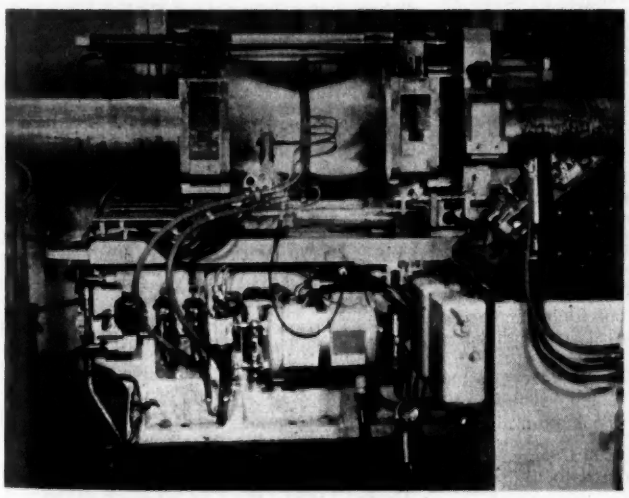
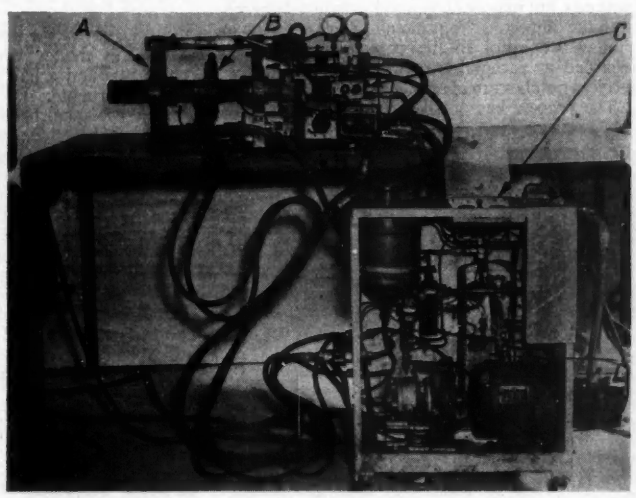


Fig. 1—The "Portsmouth" automatic pressure butt-welding machine making an 8in O.D. pipe-to-pipe weld



A—Welding head assembly. *B*—Ring burner. *C*—Control panels. *D*—Portable hydraulic cabinet.

Fig. 2—General arrangement of the portable machine for pipes of 1½in to 2½in O.D. and ¼in wall thickness

Fig. 4 and the appearance of a 5in pipe-to-pipe weld after flattening to one-quarter of its original diameter is shown in Fig. 5.

Welding has been confined to mild, carbon-molybdenum and chromium-molybdenum steel pipes, but there does not seem to be any reason why more highly alloyed pipe steels cannot be joined by this process. Post-weld heat-treatment is necessary; it consists of normalising for mild steel pipes and normalising and tempering for low-alloy steels where air hardening tendencies

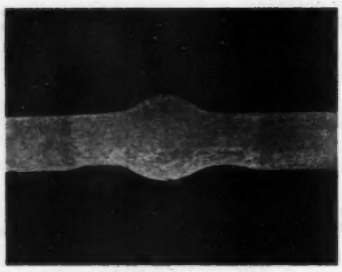


Fig. 4—Macro-etched section of 8in O.D. pipe-to-pipe weld showing grain flow

are present. Straight normalising may be carried out on the machine, but tempering heat-treatments require additional equipment.

Bend tests with either the inside or outside reinforcement removed have been used for test purposes during development and a series of test pieces for pipes of different thickness are illustrated in Fig. 6. Such tests have proved to be very discriminating and readily capable of detecting inside or outside edge weakness at the weld line. For production control the removal of a small amount of reinforcement in the form

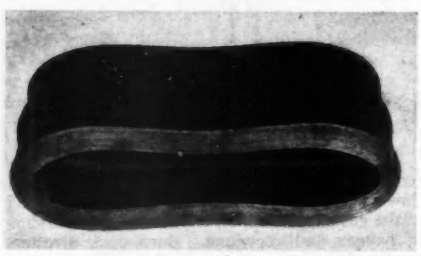
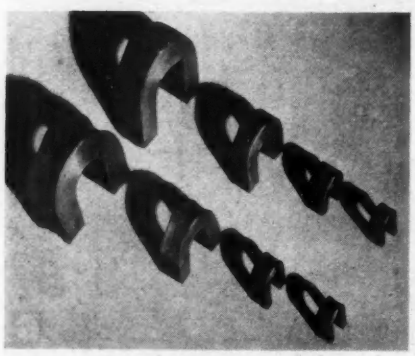


Fig. 5—Appearance of pressure butt-welded mild steel pipe after flattening to one-quarter of its original diameter

of a chip $\frac{1}{16}$in thick is practised; a surface defect will cause the chip to part at the weld line.

A micrograph of a completed mild steel pressure weld is shown in Fig. 7. The weld line is not usually distinguishable by normal etching methods, but may be shown to be richer in oxygen than the adjacent parent metal. Such zones have similar properties to the parent pipe and are regarded as acceptable provided surface metallurgical notches are absent.

The process has possible fields of application



(Upper row) Outside surface in tension.
(Lower row) Inside surface in tension.

Fig. 6—Appearance of bend test specimens from pipes $\frac{3}{4}$in, $\frac{1}{2}$in, $\frac{1}{4}$in and $\frac{1}{16}$in wall thickness

to other highly stressed components such as gas cylinders and small pressure vessels. It is fully automatic and apart from the necessity of ensuring correct setting of the machine and occasional consistency checks, highly skilled operators will not be required.

The process was originated by Mr. J. E. Burton, a Dockyard Technical Officer, and is

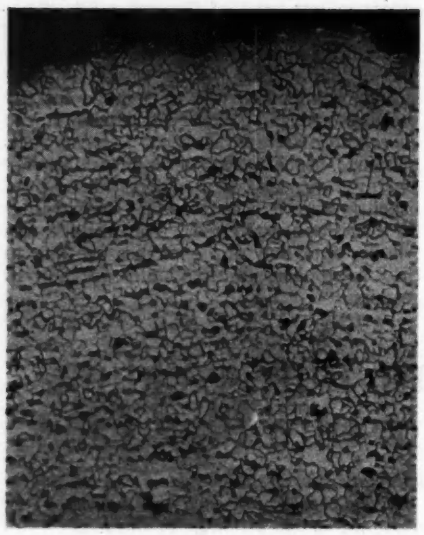


Fig. 7—Micrograph (×100) of inside surface of good mild steel weld showing complete absence of faults. The weld line is delineated by inclination of flow lines

covered by British Patent No. 706,406, which is owned by the National Research Development Corporation, 1, Tilney Street, London, W.1. We understand that the development of a commercial form of workshop automatic butt-welding machine is being undertaken by Metropolitan-Vickers Electrical Company, Ltd., under contract to the Admiralty.

Centenary of the Death of Thomas Cubitt

THOMAS CUBITT, who died on December 20, 1855, was born on February 27, 1788, the eldest son of a poor Norfolk farmer, Jonathan Cubitt, and his wife, the former Miss Agnes Scarlett. At the age of eighteen, Thomas became a journeyman carpenter in London, but deciding to travel he signed as a ship's carpenter on a frigate bound for India. Among his luggage on this voyage was a small library of books on carpentry, building and architecture, which he studied assiduously with the intention of improving his position on his return to England. He also made notes concerning the strange houses and buildings he saw on his travels and, probably most important of all, he saved the major portion of his wages. It was this money which enabled him on his return two and a half years later to set up as a master carpenter at Eagle Street, Holborn. From these small beginnings he rose to become the greatest builder of his day. A friend of Queen Victoria and the Prince Consort, he was renowned for the concern he exhibited at all times for his men. An instance of this was shown when, after the destruction of his Thames Bank factory, a year before his death, he personally guaranteed that his employees would be at work within a week, and donated £600 towards replacing their tools. With his brother William he established libraries and schools for his employees and their children, and supplied them with meals at cost price.

Thomas Cubitt married Miss Mary Anne Warner. In addition to several children who died young, they had three sons and three daughters who lived to maturity. The eldest son, George, sat in the House of Commons from 1860–1892, when he was raised to the peerage as Baron Ashcombe.

In the business which Thomas Cubitt set up in 1809 he was later joined by his younger brother William, who had served in the Royal Navy. The first large contract which the firm received was for reroofing the Russell Institution in Great Coram Street. In 1814 Thomas obtained the contract for building the London Institution at Finsbury Circus, and the document signed on that occasion and still in the possession of Holland and Hannen and Cubitts, Ltd., is the first modern form of building contract on record. It soon became clear that larger premises were needed and, the following year, Cubitt opened negotiations with Lord Calthorpe for the purchase of land extending from Gray's Inn Road to the River Fleet, but before this purchase could be completed a formal Act of Parliament was required. Once Cubitt, now aged twenty-six, had obtained the land, the stage was set for the beginning of a firm of building contractors which was unique in his day and which still bears his name.

It was an innovation of Thomas Cubitt's that he would tender for a complete building and then negotiate with the other master craftsmen to accept their contracts from him, while until then it had been the practice for the architect himself to give out separate contracts for the different parts of the work. Although the new procedure worked fairly well in practice, the system was complicated by the fact that the other master men were often also under contract to work elsewhere. The frequent delays, which resulted in penalties for Thomas Cubitt for failure to complete by the date stipulated, caused him to modify his system, once the Gray's Inn Road workshops were completed. By directly employing craftsmen of the various trades, under the supervision of more skilled foremen, Thomas Cubitt instituted one of the greatest changes in the history of building.

It was an equally revolutionary step for him to promise his men permanent work, for the building industry in those days was very precarious, and men would often be unemployed for months. As the amount of work available in London would not have been sufficient to keep his men fully employed, he bought vacant sites of land in and around London and built houses, thus becoming the forerunner of the speculative builder of a later period. This side of the business, which eventually was to become Thomas Cubitt's main interest, began in 1820, when he acquired 6 acres of land at Highbury and erected a large housing estate which he planned and designed himself. The success of this venture led him in 1824 to take a ninety-nine years' lease on vacant land belonging to the Duke of Bedford and Lord Southampton, and to plan another estate which included Upper Woburn Place, Woburn Buildings, Endsleigh Street, Gordon Street, Endsleigh Place, Gordon Square and parts of Euston Square. He planned every detail, from the drainage to the trees and shrubs in the squares, and although building regulations in those days barely existed, he planned his estates with large open spaces, which have continued to form an attraction of those parts of London which he created.

His most ambitious development scheme was perhaps that of Belgravia and Pimlico. When the work started in 1825, the area was a swamp crossed by the River Westbourne. The project, which was not to be completed until thirty years later, involved the planning and building of Belgrave Square (to the design of George Basevi), Lowndes Square, Chesham Place, Eaton Place and Eaton Square, and at the edge of the district two large houses facing each other across Albert Gate. They were so large that they became known as "Malta" and "Gibraltar"—as it was thought they would never be taken! However, the eastern house, then the largest private house in London, was sold for £15,000 to George Hudson, the railway magnate.

Thomas Cubitt's interest in town planning led him, in 1827, to leave the firm in Gray's Inn Road, and to dissolve his partnership with his brother William, so as to be able to devote his whole time to the building of the new London. William carried on as head of the firm and continued to work in close association with his brother.

While the Belgravia project was still going on, Thomas Cubitt turned his attention to the area between Eaton Place and the River Thames. Discovering that the subsoil there was gravel topped by clay, he removed the clay for brick-making and replaced it with soil from the excava-

tion of St. Katherine Docks. His activities south of the river include a large housing estate of 250 acres south-west of Clapham Common. It was owing to his efforts that Battersea Park became a national possession. The embankment above Vauxhall Bridge, of which he built 3000ft at his own expense, is another scheme for which he was mainly responsible. Later works include Queen Victoria's commission to design and build Osborne House in the Isle of Wight, and subsequently, the east front of Buckingham Palace. He also published one of the first plans for the general drainage of London, and anticipated by many years the campaign for smoke abatement by fitting smoke-consuming appliances at his Thames Bank works.

Travelling Jib Crane for London Transport Underground System

THE first of two diesel-electric travelling jib cranes specially designed and built by Taylor and Hubbard, Ltd., Leicester, to the requirements of London Transport, has now been placed in service and is illustrated on this page. This 6-ton crane is so constructed that it can be hauled in train formation through underground tunnels, for use on any site on the London underground system, at service speeds. Until this crane was introduced over 100 miles of open track—nearly a third of the system—could not be reached by rail by existing cranes owing to load restrictions, or could only be reached by making considerable detours over "foreign" lines. The design presented difficulties in so far as the crane was required to be within the "Tube" load gauge, it had to be capable of slewing a complete circle and have a tail radius which would effectively clear cable posts, platforms, &c., while offering minimum obstruction to traffic on adjacent tracks, when working. In addition, its axle loading could not exceed 13 tons.

Travelling jib crane with jib lowered for haulage through tunnels on the underground system

As constructed, the crane weighs 36 tons, and it is designed to lift 5½ tons at 15ft radius, decreasing to 1¼ tons at 35ft radius when free on rail. When blocked up the crane lifts 6 tons at 16ft radius, decreasing to 2 tons at 35ft radius.

The crane undercarriage is carried on three axles with plain bearing axleboxes, the wheels of the middle axle being flangeless and set close to the trailing axle in order to prevent fouling of the check rails on curves of minimum radius. A 37ft long swan-neck jib of rolled steel channel section is lowered on to a carrier wagon for travelling purposes as shown in the illustration.

Power for each of the individual hoisting, derricking, slewing and travelling motions is supplied by an independent 600V motor and reduction gearing. The motion speeds are as follows :—Hoisting, 5½ tons at 50ft per minute ; derricking, 6 tons at 35ft per minute ; slewing, 6 tons at 2 r.p.m., and travelling, 264ft per minute with a 5-ton load. Power for the motions can be provided either by a diesel generator on the crane superstructure or from a 600V feed from the track current rail through collector shoes, connected by a trailing cable to a power socket on the crane.

The three-cylinder McLaren diesel engine has a traction rating of 75 h.p. at 1000 r.p.m., and is coupled to a 49½kW compound-wound generator supplied by Lancashire Dynamo and Crypto, Ltd.

Electro-mechanical solenoid brakes are fitted to the hoist and derricking motions. The hoist brake has a hand release from the driving position to enable the operator to lower by gravity or to set down the load immediately in an emergency. A hand lever release on the derricking solenoid brake allows the derrick to be lowered, by gravity, on to the jib carrier wagon in the event of failure of the derrick motor. The slewing and travelling brakes are of the foot-operated band construction.

In the control gear supplied by V. G. Howell and Co., the cam-operated contactor controllers are operated by vertical lever gear in the driver's cab. Full protection is provided for all motors and limit switches in the hoisting motion prevent over winding, and in the derricking motion they limit the amount of travel in both directions.

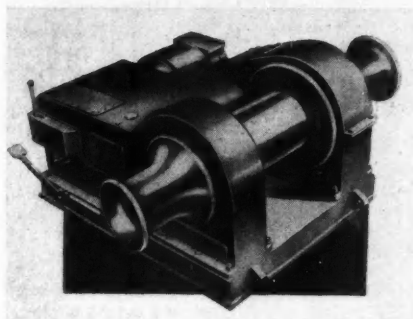
A safe load indicator fitted in the derrick rope gives visible and audible warning of both "free-on-rail" and "blocked-up" conditions. Westinghouse air brakes are fitted to the jib carrier wagon, and through pipes to both crane and carrier for use when travelling in train formation. Automatic "tube" type couplers and R.C.H. drawgear and hinged buffers are fitted on the crane and carrier wagon.

Electro-Hydraulic Cargo Winch

THE photograph which we reproduce herewith illustrates an electro-hydraulic self-contained cargo winch which has been developed by Vickers-Armstrong, Ltd. The winch has been designed so that multiple pipe runs between deck units and pumping units in the engine room could be dispensed with, resulting in a considerable saving in cost. Before embarking on the design a close study was made of the actual handling of cargo, and various problems were discussed with shipowners. As a result, an outline specification of desirable requirements was formulated and these were that the winch should be designed to combat the flexibility of a steam winch with the simplicity of operation of a d.c. electric winch ; to have a high rate of acceleration; to occupy the minimum of deck space ; to dispense with contactor control gear, and to embody simple controls and a method of automatically holding the weight in the event of a power failure. With the foregoing in mind, the company has produced a completely self-contained electro-hydraulic winch having the hydraulic drive and electric motor housed on a common bedplate. The starter, of simple marine pattern, is, however, separate and the watertight uni-directional motor can be fitted for operation from either a.c. or d.c. while all winch movements are obtained through the hydraulic drive.

The centre barrel is mounted between two cast-iron side frames and driven through single helical reduction gearing by a "VSG" hydraulic motor ; to eliminate the danger of rope jamming, the flanges are completely shrouded in the side frames. Solid drawn steel pipes connect the pump to the hydraulic motor and a valve at the pump controls the speed and direction of rotation. Above the pump assembly is a small oil tank with expansion lines led to the pump and the hydraulic motor. The electric motor, pump and hydraulic motor are mounted, together with the main side frames and centre barrel, on a fabricated steel bedplate. The starter, which as already noted is the only separate item, is normally a standard drip-proof hand-operated unit which can be mounted in the engine-room, in a deck house or adjacent to the winch.

The variable delivery "VSG" pump is fitted with automatic pressure control and the pump control is held in the full delivery position by a spring. A ram connected hydraulically to the pressure line acts in opposition to the spring, which is compressed when the pressure rises above a given value and the pump delivery correspondingly reduced, until, at a pre-set value, the no delivery position is reached. The hydraulic motor is of fixed displacement so that its output speed is directly proportional to volumetric delivery from the pump. By this arrangement the electric motor, hydraulic equipment and mechanical components are protected from overload since the maximum speed is automatically reduced to suit heavier loads. Multiple control springs are used to make full use of the power available at all speeds. Manual control is by a lever-operated, four-way, open-centre, piston valve, the lever giving the operator control of speed and direction. In the central position the pump by-passes to tank through the open centre of the control valve. Forward or backward movement of the lever controls direction while the amount of movement controls the speed to give accurate control over the full speed range for both raising and lowering.



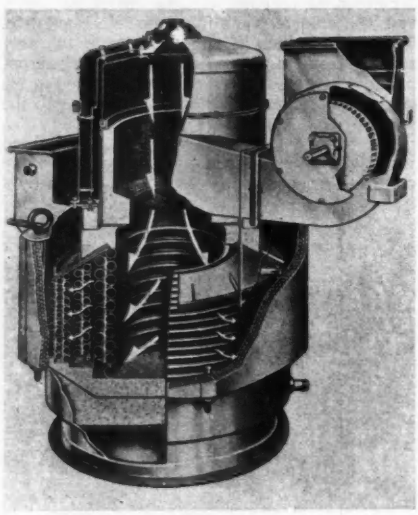
Electro-hydraulic self-contained cargo winch

In one of the side frames is an automatic, internal expanding, hydraulically-operated brake with the brake drum incorporated in one of the flanges of the winch barrel. Braking is applied by a strong spring acting at one end of the operating lever, the brake being automatically released by hydraulic pressure on a ram immediately the winch is operated. This arrangement ensures that the load is positively held by the brake when the directional control valve is in the neutral position or in the event of electric or hydraulic power failure. As an additional safeguard there is an auxiliary foot brake. Totally enclosed and splash lubricated single helical gearing is fitted in the second side frame and a small pump in the gear box provides forced lubrication to all bearings.

HIGH-LIFT HYDRAULIC LOADER.—A new high-lift design of the model "2-WL" hydraulic loader has been developed by E. Boydell and Co., Ltd., of Old Trafford, Manchester. This new model gives a maximum discharge height from the ground to the lip of the tipped bucket of 14ft 8in, and the maximum forward reach with the beams in the horizontal position is 5ft 6in from the steering tyres. The machine has a maximum safe working load of 15 cwt and can be used with either of two lightweight buckets. One bucket is of 1 cubic yard capacity and full 6ft width for coal and coke handling, and the other is of ¾ cubic yard capacity and 4ft 6in overall width for normal materials loading purposes.

Steam Generator

IT is announced that J. Stone and Co. (Deptford), Ltd., has acquired a licence to build in this country the "Vapor" steam generator, which was developed several years ago in the United States for supplying heating steam to diesel-locomotive-powered trains. These generators



Arrangement of the "Vapor" forced circulation steam generator

are made in seven sizes with steam capacities from 500 lb per hour and upwards.

As can be seen from the sectioned photograph we reproduce above, the "Vapor" steam generator is a compact, forced-circulation, water-tube boiler with several sets of coils nested and connected in series to form a single coil through which the feed water passes once only. The water is not recirculated and the generator has no drums, headers or internal reservoirs. Fuel supply to the burner is automatically regulated in the proportion required to heat the amount of water passing through the coil at any one moment.

High turbulence in the pressurised combustion chamber forces the hot gases to scrub the coil surfaces and wipe off any insulating film of relatively cool gas. The combustion air is pre-heated in an air jacket surrounding the upper part of the fire pot, and is delivered under forced draught to the burner where it mixes with the atomised fuel oil. The hot combustion gases are driven down and across the nested coils which are staggered to ensure maximum contact. The fire is adjusted to evaporate about 90 per cent of the feed water admitted to the coils. The unevaporated water travels at high speed, carrying scale-forming sludge into a steam separator. In the separator the sludge settles to the sump, and the steam passes through the coil outlet. It is claimed that the thermal efficiency of the generator is from 79 to 82 per cent throughout the whole modulating range.

Protection against breakdown is provided by a servo control which shuts down the unit completely if the water supply falls below a safe minimum. A temperature limit control safeguards the coils from the chance of an abnormally high steam temperature due to low water flow. It is pointed out, however, that due to the relatively small mass of water in the coils, even under full operating conditions, there is at no time any danger of explosion. In the event of flame failure the water flow is automatically checked either by a pressure switch, or a stack switch.

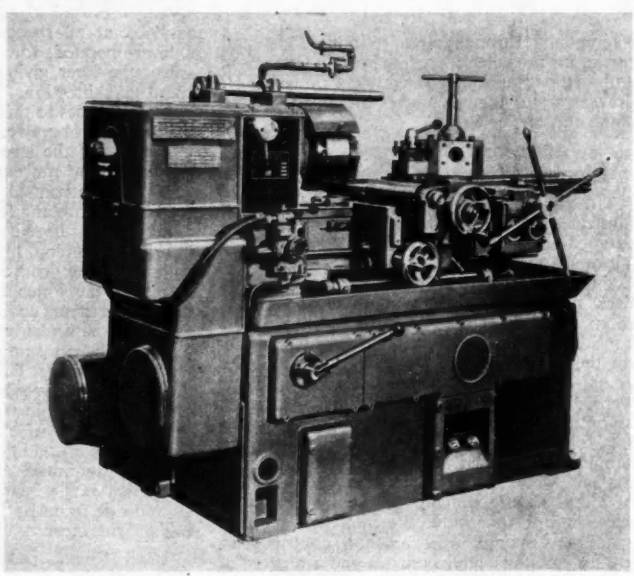
Capstan Lathe

A NEW capstan lathe now being made by Murad Developments, Ltd., Stocklake, Bucks, has a centre height of 6¾in, a spindle bored 2 1/16in in diameter, swings work up to 7in diameter over the cross slide, and admits work up to 18in long between the collet and turret face. This model "3 C" lathe is illustrated below.

The rigid cast headstock carries the spindle in preloaded anti-friction bearings at the front and a floating roller bearing at the rear. A two-speed motor drives a two-speed gearbox through vee-grooved pulleys, and from the gearbox the drive is transmitted by quadruple vee ropes to the spindle. Through this arrangement sixteen spindle speeds from 51 to 1500 r.p.m. are made available in four groups of four speeds. Pedals in the cabinet base control the two-speed motor, so that for any one of the speed ratios between the motor and gearbox there are four speeds available without stopping the motor.

The cross slide is fitted with a slotted indexing stop bar which can be set to trip the automatic surfacing feed as well as to provide a rigid stop when making accurate depths of cut. Movement of the slide is by a large handwheel with an adjustable micrometer dial. Automatic surfacing feeds are provided for both directions of cross slide movement and for the sliding motion. The feed gearbox is attached to the turret and is driven from the main spindle by a feed shaft along the front of the bed. From this box power is transmitted to the apron by a short feed shaft which passes through the reversing gearbox attached to the main gearbox. The feed box gives six rates of longitudinal feed from 0·0025in to 0·024in per spindle revolution, and six surfacing feeds from 0·0012in to 0·012in per revolution.

The turret is indexed by the capstan handle and is geared to six adjustable stops at the rear; it can be located and clamped at different positions along the bed to suit the work being machined. This slide has a maximum stroke of 6½in and is provided with six automatic feeds from 0·002in to 0·019in per revolution of the spindle.



2in capstan lathe with six rates of sliding and surfacing feeds and 6½in turret slide with six automatic feed rates

The coolant pump is driven by a separate motor controlled by a switch on the main control panel. A pneumatic bar feed available with the machine is designed to handle the heaviest bars and is operated by air at from 20 lb to 30 lb per square inch.

Continental Engineering News

Light Alloy Shuttering

Substantial savings in erection and dismantling costs are claimed for the light alloy shuttering, principally for tunnels and similar sections, shown in the accompanying illustrations. The shuttering is manufactured by Aluminium Industrie A.G. Chippis, Lausanne, and Albert Aeberli Konstruktionswerkstätte, Zürich.

The assembly consists of light alloy rings of extruded bulb tee section, to which are attached the sheets which consist of extruded light alloy

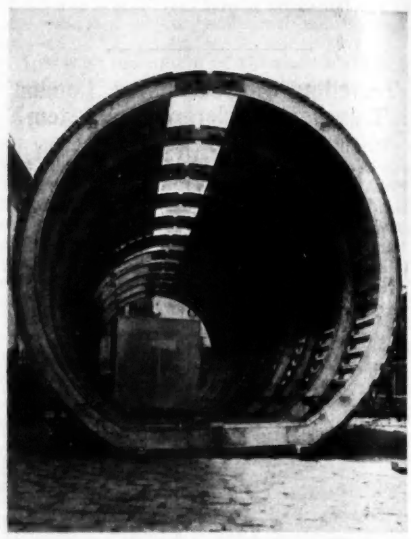


Fig. 1—Example of light alloy shuttering showing the manner of assembly of the rings and M-section sheets

"M" sections (Fig. 1). By means of cast aluminium wedge clamps, which slide on the centre rib of each shuttering plate, these plates are fastened to the rings (Fig. 2). No tool other than a hammer is required for assembling. The plates are given a transverse curvature greater than that of the rings. This enables them to be used over a range of diameters and facilitates clamping by allowing the clamps to deform the plates elastically in pulling the centre ribs towards the rings. When the concrete has been poured and vibrated, the small gap left between

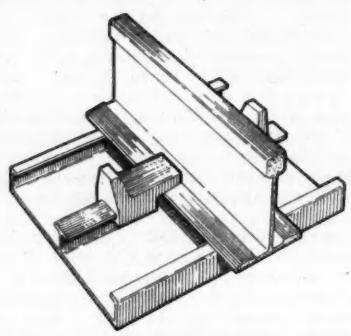


Fig. 2—Method of assembly of shuttering and arch, by means of cast aluminium wedges on the centre rib of the shuttering plate

the central rib and the ring is closed by the external pressure, with the result that the clamps are slackened off slightly and can more readily be removed.

In erecting the shuttering, the ring sections—two per arch—are first placed in position at distances of about 1m or less, depending upon rock conditions, and assembled with pins and cotters, as shown in the first illustration. They are then clamped by attaching a number of shutters at convenient points along the circumference, after which the remaining shutters are inserted in succession as the concrete is poured, with short lengths of sheet being used

for the final top portion of the arch. In dismantling, the arches are collapsed by withdrawing the pins and the shuttering is removed. Where the diameter is sufficiently large to permit the passage of a truck with folded shuttering mounted on it, the method of telescopic shuttering can be employed. In that case, openings for pouring the concrete are made by withdrawing plates at the required height.

By virtue of the high strength/weight ratio of the alloy, specific weights of 16 kg per square metre for the shuttering and 3 kg to 7 kg per metre for the rings, are achieved. These figures, it is claimed, are about 50 per cent of those needed with either steel or wooden shuttering, and, as a result, larger pieces can be handled. Total working times, including oiling, assembly, dismantling and cleaning, are stated to be well below those for steel. The shuttering is reported to have been used over 300 times in some instances, without reaching the end of its useful life. Rough (keying) surfaces can also be produced where required, by omitting the oiling of the shutter plates, which are subsequently cleaned of adhering concrete by chemical treatment.

A minimum number of assembly elements is used, i.e. only wedges, pins and cotters. By bending-up the web ends, the wedges can be prevented from sliding off the plates and pins and cotters are safeguarded against loss by being attached to the arches by chains. In this manner, wastage of small parts is reduced to a very low figure.

The shuttering which, it is stated, will shortly be manufactured under licence by Imperial Chemical Industries, Ltd. is being handled in this country by John Nutting (Exports), Ltd., 3, Cork Street, London, W.1.

Bavaria Sets Up Atomic Commission

The "Bavarian State Commission for the Peaceful Uses of Nuclear Energy," comprising twenty-eight members, including the Nobel prize winner, Professor Heisenberg, has been established under the chairmanship of Minister-President W. Hoegner. Thus Bavaria, in setting up its own nuclear authority, has anticipated the Federal Government, which it has been stated is planning an atomic energy commission at national level.

Before purchasing for Bavaria a research reactor, that question as well as that of the future procurement of nuclear fuel, would be discussed with the Federal Minister for Atomic Questions, said President Hoegner. Present plans provide for the erection of the reactor at Eching, some 12 miles from Munich, the cost being estimated at DM.15,000,000. The Physical Institute of the Max-Planck Society which has been transferred from Göttingen to Munich, will have its new building on the northern outskirts of the city. This is scheduled for completion in 1957.

Integral Coach Factory at Perambur

BY OUR INDIAN CORRESPONDENT

THE Indian Railways have been short of coaches for a long time, the present requirements being of the order of about 12,000 coaches. There is very little coach-building capacity in the country and consequently most of the requirements have to be met through imports from abroad. In 1949 the Railway Board adopted all-steel construction as the future standard for coaches and an order for 100 coaches was placed with the Hindusthan Aircraft, Ltd., Bangalore, and plans were set in motion for the manufacture of integral design coaches at home. In this kind of integral coach the body and underframe form an integral unit, thereby reducing the weight by about 20 per cent, as compared with standard stock, and affording a higher payload. At the Integral Coach Factory at Perambur these coaches are now being made in collaboration with the Swiss Car and Elevator Manuturing Company, Ltd., of Zurich, acting as technical advisers. The factory was opened on October 2nd by Mr. Jawaharlal Nehru, the Prime Minister.

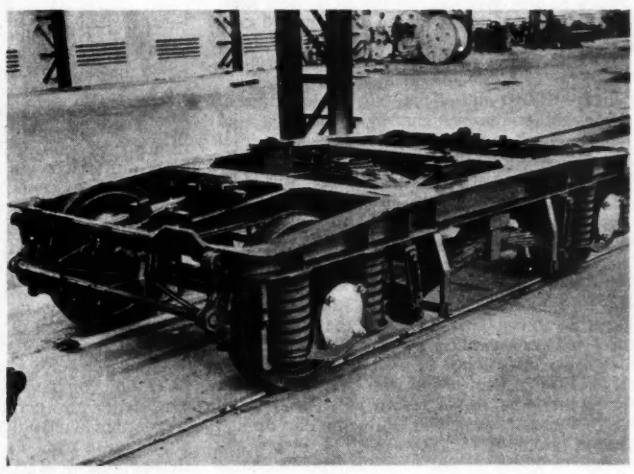
The factory, the biggest of its kind in this part of the world, cost about Rs. 8 crores (£6,000,000) and will have an ultimate production capacity of 350 coaches per year. Its construction was commenced about three years ago and the total covered accommodation provided is about 860,000 square feet in ten structures. The biggest building is the main assembly shop, covering an area of 261,670 square feet. This shop, the biggest in India, is 1000ft long, 260ft wide and consists of two bays of 80ft and two bays of 50ft spans. The high 80ft bays carry gantries for 20-ton cranes throughout the length of the shop. The whole of the steelwork in the shop, totalling about 2000 tons, is welded, and this is the first time welded fabrication has been used in India on such a large scale. The welding and the erection were done by Indian contractors, the erection, it has been stated, taking about eight months from the start.

After the general layout of the factory was drawn up in collaboration with the Swiss firm of consultants the engineers preparing the plant and machinery list were faced with the task of compiling the time required for each operation on particular machines, and as this form of coach construction is entirely new to India they had no precedent to follow or guide their calculations. The question was to decide the ratio of production of a Swiss worker to that of an Indian worker, a classic question which is perhaps the measure of the dilemma facing an Indian or Asian engineer charged with the task of applying essentially foreign methods of production to indigenous conditions. The answer, says a report, was not readily available, though several experts in India and the International Labour Office were consulted. Detailed examinations were therefore made by a Swiss team, which visited different factories in India, and the conclusion was reached that the ratio in the case of a machine operator "may be 1 : 1·8." This question was also discussed at Geneva with the experts of the International Labour Office, who agreed that the ratio was reasonable. Based on the man-hours arrived at from this ratio, the approximate requirements of the various kinds of machines were finalised. Most of the machinery was purchased from Europe, the total order being valued at £788,000.

The lightweight all-welded steel coach made in the factory incoporates many new features, according to the factory's chief technical manager, a member of the Swiss consulting staff. The saving in weight per bogie amounts to 23 per cent in comparison with the standard Indian Railway bogie. This has been achieved by using welded construction throughout on the bogie frame and the bogie bolster. The wheels of the new coach are of the European standard, 3ft diameter, as against the conventional Indian standard of 3ft 7in. As the total weight of the "Schlieren" bogies is approximately 7 tons lighter than the conventional two bogies, the axle load is reduced by nearly 2 tons.

The axlebox springs are arranged on either side of the axlebox, as can be seen in the accompanying illustration, and the bogie has also two bolster laminated springs arranged longitudinally, on which the bogie bolster is directly supported. The longitudinal spring leaves have a special channel profile, providing the spring with a cavity throughout the whole length of the leaves after they have been assembled. These cavities provide a means of permanent lubrication, as they are capable of storing a considerable amount of lubricant, thus improving its shock-absorbing capacity. The bolster springs are suspended by swivelling hangers to the bogie frame, and these take up the lateral shocks as well as side swinging of the running gear. The bogie bolster is connected by two longitudinal anchor links to the bogie frame. These anchor links are said to be an improvement over sliding plate guides usually located between the cross member of the bogie frame and the bogie bolster.

The bogie frame is of all-welded construction, made up of mild steel flats and sections, some of which are pressed to the required shape. Special attention has been given to the connections between the longitudinal and the cross members of the bogie frame to ensure the best possible uniform stress distribution. The braking arrangements on the bogie are designed in such a way that the additional stress, normally taken by the centre pivot in conventional bogies, is distributed over reaction points fixed on the underframe. The centre pivot is therefore subjected to less wear and tear and the free play of the bogie is unaffected during braking.



Indian Railways integral coach factory at Perambur, Madras, and bogie for the Schlieren integral coach designed and built for service on Indian Railways

Industrial and Labour Notes

Industry and the Economy

The information division of the Treasury has included in the latest number of *Bulletin for Industry* some observations and statistics on industrial activity this year in the United Kingdom. It says, for a start, that 4 per cent more goods and services were bought by the personal consumer up to the middle of the year than in the first half of last year. Average consumer prices were higher by some 3 to 4 per cent, so that the actual expenditure was higher by 7 per cent.

In the first three-quarters of this year there was an increase of 6 per cent in the volume of exports, at prices averaging 1½ per cent higher than a year earlier. An outstanding increase was by the chemicals industry, which raised the value of its shipments by 14 per cent. In the main metal-using trades there were increases in value of 8 per cent in machinery and electrical goods and 6 per cent in road vehicles and aircraft. The *Bulletin* goes on to say that the limited information at present available points to a substantial rise in industry's demand for investment goods. The total area of industrial building started in the first half of the year was two-fifths bigger than a year earlier, and the production of metal-working machine tools for the home market was higher in value by 15 per cent. With order books growing a good deal faster than machine tool production, orders on hand in the middle of the year were higher by 32 per cent ; approvals for factory buildings by the end of September were up by 45 per cent.

Other matters recorded in the *Bulletin* are that in the first nine months of this year industrial output was 5 per cent higher than in 1954, and that the demand for labour has been very high. Employment in September was 1·2 per cent higher than a year earlier. In the first forty-five weeks of the year, despite the fine summer and the railway strike in June, coal consumption was 800,000 tons higher than in the comparable period of last year and 10 per cent more electricity was sent out. In the same period coal output was lower by nearly 3,000,000 tons, despite a big increase in opencast production. Total deliveries of finished steel were up by 9 per cent in the first half of the year, home output of crude steel has been higher by 6½ per cent, and imports are being brought in this year at a level equivalent to a tenth of home crude output.

Iron and Steel

The Iron and Steel Board has stated that, in November, Britain's steel production averaged 408,600 tons a week, and was thus at an annual output rate of 21,246,000 tons. This was the highest rate ever achieved. The Board says that there is now a good prospect that this year's steel production will now reach 19,750,000 tons. Next year, it is hoped to increase production to 21,000,000 tons. Pig iron production in November was also a record at an average of 252,000 tons a week. It represented an annual output rate of 13,135,000 tons.

On Thursday of last week, several questions about steel production and stocks were answered in the House of Commons by the President of the Board of Trade, Mr. Peter Thorneycroft. He said that over the first eleven months of this year the annual rate of steel production was 19,800,000 tons. The stocks of steel held in the United Kingdom on June 30th last by producers, users and merchants totalled 4,400,000 tons. In reply to a question about the present production and stocks of steel in Wales, the President said that the annual output rate there during the first eleven months of this year was 5,900,000 tons. Production for the complete year was expected to be at about that rate, which would be 9 per cent higher than in 1954. The stocks of steel held in Wales by producers, users and merchants on June 30th last were 281,000 tons.

Pig Iron Prices

The Iron and Steel Board has announced increases in the prices of basic pig iron, hematite pig iron, low phosphorus foundry iron, and Scotch foundry iron, all of which became effective last Monday, December 19th. These changes, it is stated, are necessary to take some account of the higher cost of ore, particularly the increase in the cost of ocean freight of imported ore. The increases in basis prices are : basic pig iron, 11s. 6d. a ton ; hematite pig iron, 17s. 6d. a ton ; low phosphorus foundry iron, 16s. a ton, and Scotch foundry iron, 7s. 6d. a ton. There are also increases in the extras for low phosphorus, high silicon and manganese content.

It is stated that no changes are at present being made in the maximum prices of steel products determined by the Board.

Wage Demands

The British Employers' Confederation has this week commented on the fact that, since the beginning of this year, about 12,000,000 workpeople have benefited from increases in weekly wage rates, totalling over £5,000,000. The effect has been to raise the Ministry of Labour index of wage rates by about 7 per cent. As the national wages bill in 1954 was estimated at over £6000 million, inclusive of overtime earnings and bonuses, the Confederation suggests that this year the increase in total annual wages costs will almost certainly be over £400 million. It goes on to say that current or pending wage claims affect about 7,500,000 workers, the majority of whom have already received a wage increase under earlier settlements made during the year.

These claims, the Confederation continues, have not all been formulated in precise terms, though some indication has been given in most cases as to how the trade unions interpret such words as "a substantial increase." If these claims were granted in full, the Confederation asserts, weekly wage rates alone, exclusive of overtime earnings and bonuses, would go up by over £6,000,000, which would raise the Ministry of Labour's wage rate index by about 8 per cent. Translating that into terms of the total annual wages bill, the increase would be another £500 million, and none of the figures, the Confederation adds, makes any allowance for salary increases or claims. The Confederation takes the view that increases of this magnitude far outstrip any likely concurrent improvement in the real national income. Thus, it is commented, the T.U.C.'s recognition that rising costs and prices are the biggest threat to our balance of payments, to continuing full employment and to living standards takes on a special significance. On this broad issue there is agreement between the British Employers' Confederation and the Trades Union Congress. Moreover, the Federation of British Industries has recently urged its members to avoid price increases wherever the level of costs leaves a choice open in the determination of selling prices.

What is certain, the British Employers' Confederation emphasises, is that no class of workers can secure any permanent improvement in its standard of living unless our national productivity continues to rise. Persistence in the assumption that because workers in some industries have had increases all must do so will inevitably perpetuate inflation and bring about the consequences feared by responsible trade union leaders and employers alike. At some point of time, the Confederation remarks, a halt must be called, and, when that happens, some industries will have "to reconcile themselves to stopping where they are in the leap-frogging queue."

Cement Prices

Last week, the chairman of the Cement Makers' Federation, Sir Malcolm Trustram Eve, stated that all the makers of Portland cement had agreed that there would be no increase in the present price of cement anywhere in the United Kingdom, until at least June 30, 1956. Sir Malcolm explained that all the ten independently controlled cement makers felt that it had become vital in the public interest that some positive and definite action should be taken to slow down the inflationary spiral. The hope was that other industries would feel able to take similar action.

The risks involved, Sir Malcolm continued, were not negligible. Cement makers could undertake to continue to improve the efficiency and quality of their manufacture, but could only ask that others who were responsible for well over one-half of their manufacturing and delivery costs could help by keeping their prices stable. Increased production and efficiency had helped so far in keeping down the costs and stabilising cement prices, and until the increase in the price of coal last summer forced a rise nearly all cement prices had remained unchanged for seventeen months. Sir Malcolm added that the reason the cement industry could not promise a period of stable prices longer than six months was that much more than one-half of the costs were the concern of others. Cement costs depended to a very large degree on prices of coal, power and transport. If cement makers could know for certain that the charges fixed by the National Coal Board, the Central Electricity Authority, and the British Transport Commission would not rise for a named period, the period of promise of "six months at least" might well be extended.

Coal

The National Coal Board's latest statistical statement shows that, in the third quarter of this year, there was a deficit of £4,970,582, compared with a deficit of £4,000,000 in the corresponding quarter of last year. It is pointed out that the third quarter usually yields the worst financial results of the year, owing to the incidence of the holidays.

The statement explains that in the third quarter this year the saleable coal from the National Coal Board's mines totalled 46,474,855 tons, of which 43,571,583 tons were "disposable commercially." The total costs of production were £162,878,798, and the proceeds of sales were £162,997,250, the trading profit, before charging interest, thus being £118,452. The estimated profit on opencast working for the quarter was £1,910,000 and the estimated profits of the Board's ancillaries were £334,000, making the total profits £2,362,452. The losses incurred on imported coal, however, together with the estimated interest payable to the Minister of Fuel and Power brought about the deficit on the quarter's activities.

The Board says that, in addition to the general factors which operate in a summer quarter, particularly annual holidays, there were heavier losses on imported coal, and increased expenses had to be met, including higher rates of National Insurance and higher railway rates and dock charges. Attention is drawn in the Board's statement to the profit of £1,900,000 on opencast operations. The opencast output in the quarter was 3,400,000 tons and the profit over 11s. a ton. The working of coal by opencast methods, the Board claims, is now on a soundly profitable basis and should bring substantial benefits to the national economy in the future.

Fuel Conservation and Productivity

The British Productivity Council has published an "action pamphlet" entitled "Fuel Conservation and Productivity," which sets out the main factors for ensuring that fuel costs are cut to the minimum. The pamphlet points out that this year this country, for the first time in its history, has imported more coal than it has exported, the cost in foreign exchange being put at £80,000,000. If, the pamphlet says, all users of coal could make only a 10 per cent reduction in their consumption, at least 2,000,000 tons would be saved in a year, which would represent £14,000,000 in our balance of payments. At present, the pamphlet notes, our coal stocks are a little better than they have been, though a severe winter or a drop in production from the mines could reduce them very rapidly to a point where cuts to consumers might be inevitable. Further, it is commented, since the 18 per cent rise in price a few months ago, managements will not need to be reminded of how big a part of their costs coal often absorbs.

National Metal Congress and Exposition

BY OUR AMERICAN EDITOR

No. II—(*Continued from page* 889, *December* 16*th*)

AN important new metal cutting process was demonstrated for the first time at the stand of the Linde Air Products Company, of New York. The method is known as "Heliarc" cutting, employs a gas-shielded arc and permits non-ferrous metals to be cut and shaped quickly and easily. The cuts are of saw-like quality and the high cutting speeds attainable with the process tend to reduce processing costs. The process employs a constricted arc of extremely high temperature and high velocity between a tungsten electrode and the non-ferrous workpiece. This concentrated energy of the arc stream melts and ejects a thin section of metal. The jet-like action of the arc stream is mechanical, and gas shielding of the cutting zone protects the cut face from oxidation.

Heretofore, there has been no process for cutting non-ferrous metals comparable to oxy-acetylene cutting of steel. Usually, saws and planing devices have been used for making straight-line cuts, and contoured cuts were generally made on a bandsaw or by hand-chipping or drilling methods. All the advantages of oxy-acetylene cutting of steel are now brought to a metal such as aluminium. For example, ½in thick aluminium can be cut at 300in per minute, and the cutting speed is 125in per minute for

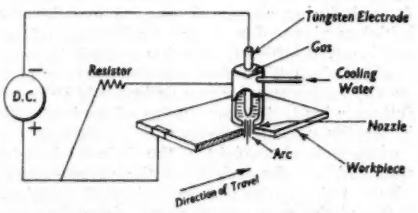


Fig. 4—Diagram of "Heliarc" gas-shielded tungsten electrode arc cutting process

¼in thick material, 75in per minute for ½in plate and 50in per minute for 1in material. Slower cutting speeds may be obtained by adjusting the controls, and the process lends itself to mechanical or manual operation in any position for cutting straight lines, bevels, circles and shapes.

With few exceptions, the cutting equipment is the same as that used for inert gas-shielded tungsten-arc ("Heliarc") welding. A new collet and collet body are required in existing machine and manual welding torches, and the nozzle itself is completely different. Another change is the addition to the control apparatus of a "pilot arc" circuit which is used to initiate the cutting arc. In this circuit a resistor limits the current from the power supply to the nozzle. The shielding gas differs from that used for welding. The best results obtained so far have been with a mixture of argon and hydrogen. For machine cutting, a mixture containing 65 per cent argon and 35 per cent hydrogen has been most satisfactory. The optimum mixture for manual cutting is one with about 80 per cent argon and 20 per cent hydrogen. In the latter case, the lower hydrogen content provides greater tolerance for variations in the arc length than is required in machine cutting. In manual cutting operations, pure argon is used to initiate and maintain the pilot arc which precedes the cutting arc. Once the cutting arc starts, hydrogen is automatically added to the flowing argon to provide the required mixture.

Two different methods of starting are used with the process. One is for mechanised operations, while the other is more suitable for manual cutting. Mechanised cutting requires the use of a high-frequency unit in conjunction with the pilot circuit for starting the cutting arc. In manual cutting, a pilot arc is used in an argon atmosphere to start the cutting arc. An important factor in determining the ease of starting and the maximum arc length that can be maintained in the argon-hydrogen mixture is the open-circuit voltage rating of the power equipment, which should be at least 80V. Most of the development work so far has been done on cutting of aluminium. Although preliminary investigations of cutting techniques for other non-ferrous as well as ferrous materials show promise, no definite recommendations can be made as yet by the manufacturer.

Flame-plating is another interesting process which was demonstrated by the Linde Air Products Company at this year's Metal Show. It is a surfacing method in which particles of tungsten carbide are blasted on to the surface of the workpiece, through the use of a specially constructed gun. Particles of tungsten carbide are fed into the chamber of the gun and are suspended in a mixture of oxygen and acetylene. When this mixture is ignited, a detonation takes place. The detonation wave travels at ten times the speed of sound through the barrel, heating the particles to plasticity, and giving them a supersonic velocity. The particles are hurled out of the barrel and embed themselves in the surface of the workpiece where a microscopic welding action takes place, producing a tenacious bond at the interface. Although the temperature of the gases inside the gun barrel reach 6000 deg. Fah., the temperature of the part being plated seldom exceeds 400 deg. Fah. Thus, there is little chance that the part being plated will warp or that the metallurgical properties will be changed. Successive detonations build up the coating material to the desired thickness, generally from 0·002in to 0·010in. Extensive tests indicate that the coating is satisfactory in its resistance to frictional and abrasive wear. Flame-plated parts have shown wear resistance superior to solid sintered tungsten carbide, hard chrome plating and tool steels. In addition, the plated parts have a greater resistance to mechanical shock than solid sintered tungsten carbide.

There are some limitations in applying the process, and it is not suitable for use on parts such as steam shovel teeth or caterpillar treads, where literally inches of wear are permissible. The shape of a part, too, has to be considered before flame-plating. Because the coating is formed by particles striking the surface at very high speeds, only those areas which allow the particles free and sufficient access will be plated evenly. This eliminates narrow holes, blind cavities and deep, vee-shaped grooves. Plating "around sharp corners" sometimes is unsatisfactory because a weak spot may result at the corner. Flame-plating is not recommended for metal-cutting edges because the coating will not stand up under this service. The coating is thin; consequently, insufficient material is present for resharpening. The flame-plated coating should not be expected to protect parts from corrosion; it was developed for resistance against abrasive wear and not against the effects of acids or alkalis.

The hardness of the flame-plated tungsten carbide coating averages about 1350 V.P.N. which is theoretically equivalent to about 89·3 Rockwell A. Actually, the particles that make up a flame-plated coating are harder than indicated by the Vickers test. The difference between the actual particle hardness and the measured hardness is due to the cobalt matrix. The matrix, while lowering the measured hardness, does not impair the usefulness of the coating; on the contrary, it results in an unusual combination of hardness and flexibility not commonly associated with hard metals. The ultimate result is a longer wear life than that of other materials having a higher measured hardness. The modulus of elasticity of flame-plated tungsten carbide is surprisingly low, being approximately 27,000,000 lb per square inch as compared to 64,000,000 to 92,000,000 lb per square inch for sintered tungsten carbide. This great difference in the elasticity is attributed to the unusual bond between the individual particles in the coating. Some authorities believe that hard materials with a low modulus of elasticity have a greater resistance to wear. They reason that even a light load will cause a slight deflection of the coating which will distribute the load over a larger portion of the bearing surface, thus prolonging the wear life of the part. Since it has a composition of 92 per cent tungsten carbide and 8 per cent cobalt, reagents that attack cobalt will attack flame-plated coatings. These reagents include most acids and some alkalis. Mild alkalis, detergents, lubricating oils, and atmospheres free from acid fumes in a majority of cases have no detrimental effect on the coatings.

The flame-plated tungsten carbide coating may be used in the as-coated condition or finished to various degrees of smoothness by several standard finishing methods. The as-coated surface is comparable to that of fine emery paper or approximately 125 micro-inches r.m.s. This surface is used without grinding or polishing for many non-precision applications. The as-coated surface is of the proper degree of roughness to provide added gripping power to such parts as gripping dogs and collets. Non-precision parts that require a fairly smooth surface can be given an intermediate finish of approximately 20 to 100 micro-inches r.m.s. This can be accomplished by lapping, flexible belt grinding, or brush finishing. Where close tolerances are required, the flame-plated coating must be ground and lapped, and finishes of 0·5 micro-inches r.m.s. smoothness can be produced.

A small, low-cost, direct-reading spectrometer ("Spectromet"), which has been developed for use directly on the floor of the foundry and melting shop was shown by Baird Associates, Incorporated, Cambridge, Massachusetts. The design of the instrument (Fig. 5) incorporates the basic requirements for simple analytical problems of up to eight elements in a single matrix. The instrument offers the smaller organisation the great advantage of automatic analysis without the air-conditioned laboratory. The cost of such laboratory space is now avoided by making the instrument insensitive to works environment. The instrument produces data directly on dial indicators in the form of element concentrations so that complex calculations are avoided completely. Further economic advantages are gained in the matter of operative personnel. One regularly trained person, probably originating from the "shop" may operate the spectrometer. Thus, the instrument makes an important contribution to industrial productivity by providing practical analytical data at greatly reduced cost.

To obtain freedom from the effects of works environment a special optical design has been adopted. All components are mounted in a sealed container 14in in diameter. The focal curve, entrance optics, exit slits and photo-multipliers are enclosed in an airtight compartment at one end of the container. At the opposite end a smaller enclosure covers the concave diffraction grating, and the entire system is sealed against dust. Light from the analytical gap enters the compartment through a quartz window. Photo-multipliers are connected to the electronic measuring system through airtight connectors. The container, compartment and end cap are insulated against thermal shock. The container itself is the structural member supporting the optical system, and in turn this structure is supported kinematically and is shock-mounted. Using an original 4in diffraction grating, having a 3m focal length and 15,000 lines per inch, a first-order spectral range of approximately 2000Å is available at the focal curve. Problems requiring second order spectra can be set up with 1000Å being available.

The instrument is equipped with an automatic servo monitor mechanism which continually maintains optical alignment. It automatically keeps the spectrum lines centred in their exit slits without adjustment by the instrument operator being necessary. The highly successful and reliable measuring circuit used in the Baird standard direct-reading spectrometer, employing a logarithmic measuring system is used in the

Fig. 5—Direct-reading spectrometer for analysing up to eight elements

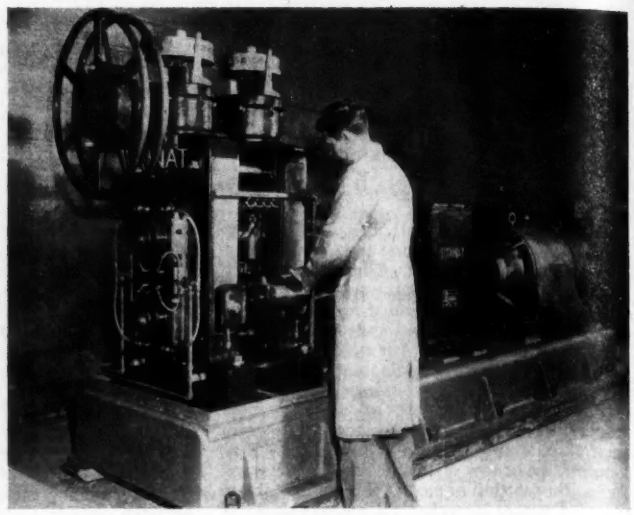


Fig. 6—Stanat 10in wide backup-driven four-high rolling mill with 2½in to ¾in diameter work rolls

"Spectromet." The concentrations of elements (per cent) are read directly on indicators situated at a convenient height on the front of the instrument. The samples are prepared in less than a minute on special sample preparation equipment. They are placed in the instrument, the loading door is closed, and the start button is pushed. Thirty to forty seconds later the results of the analysis are read on the calibrated indicators. The operation is completely automatic, and the single push button is the only exterior control mechanism.

A high-precision electronic tensile testing instrument (Fig. 6) was displayed at the stand of the Instron Engineering Corporation, Quincy, Massachusetts. It makes possible the testing of a variety of materials, over a wide field of test conditions of load and speed, with load ranges from 2 grammes to 5000 lb full-scale. The instrument is designed and built to measure accurately the load-elongation properties of such materials as textile fibres, yarns and fabrics, plastic films, coated materials and laminates, rubber, paper, rope, leather, adhesives and similar fibrous or non-fibrous specimens. It is also well suited for the tear testing of fabrics, plastics films and similar special applications where the magnitude and shape of the quick variations in load are especially important and are detected only in a low-inertia system. The instrument utilises an electronic weighing system for detecting and recording the load applied to the sample under test. The pulling jaw is operated by a drive that provides an absolutely controlled rate of elongation of the sample, over a wide range of speeds and in either direction of travel, and with instant reversibility. The chart of the high-speed recorder is driven at various speed ratios with respect to the pulling jaw, so that tensile load-elongation curves of the material are made accurately, at constant rate of elongation.

The pulling jaw of the instrument is mounted on a movable crosshead which is operated vertically by means of twin screws. The main power to actuate the pulling crosshead is derived from a servo-controlled amplidyne drive acting as a "positional follow-up" system. By this means, a low-power reference unit, which is driven synchronously at various speeds through a set of light change-gears, is able at all times to determine the position of the movable jaw. Likewise, instantaneous starting, stopping and reversal of direction of travel of this jaw is effected through fast-acting magnetic switches operating on the reference unit. Therefore, since almost no lag or error is introduced at reversal, this system enables measurements to be made of hysteresis under cyclic conditions, accurate correspondence between head position and chart travel being maintained at all times. The operation of the pulling head is controlled by push buttons which start, stop or quickly reverse the motion of the movable jaw. The operation can be made automatic by a set of adjustable, close-tolerance switches, which control the gauge length, the cycling points, and other functions. Emergency stops are provided which will automatically stop the machine at the extreme ends of crosshead travel to prevent damage to the equipment. Standard jaw speeds are provided extending from 0·02in to 20in per minute in twelve steps. Change of speeds is effected easily through the use of light gears mounted in an accessible compartment on the control panel, in conjunction with a shift lever conveniently situated on the right side of the instrument. Rapid traverse controls are available for quickly moving the crosshead from one position to another, or for returning the head to the correct established gauge length after a previous test has been completed.

The heart of the load recording system consists of a set of sensitive load cells based on the electric strain gauge principle. Load variations produce electrical signals which are amplified and made to operate a high-speed graphic recorder. Like the pulling jaw, the chart is synchronously driven at various speeds so that the resulting trace is an accurately drawn load-elongation curve of the material, at a constant rate of elongation. The standard chart speeds which are provided cover the range from 0·2in to 50in per minute in ten steps. The easily interchangeable load cells provide five groups of ranges extending from 10 grammes full scale to 5000 lb in twenty-six steps. An ultra-sensitive range of 2 grammes full-scale is also provided. The value of full-scale load sensitivity may be switched instantaneously and with perfect accuracy to any other range within the capacity of the cell in use. This operation is often performed during an actual test, to magnify the initial portions of a curve. Calibration of the cell is easily achieved in a few seconds through the use of small weights, and the operator may set the instrument for any desired odd value of full scale load. The zero point of the load cells is readily adjustable, thus compensating for variations in the weight of the different jaws in use, and for the weight of the sample itself. Most of the errors due to accidental misalignment of the jaws are avoided, since the construction of the cells permits only the axial component of the load to be detected. The cells are mechanically protected against damage due to possible overloading in either direction.

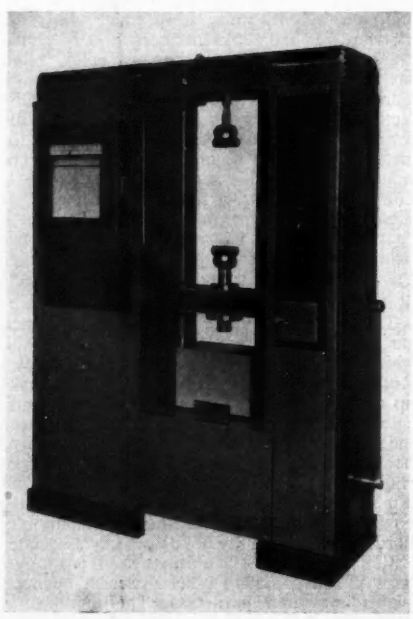


Fig. 7—Instron 5000 lb electronic tensile testing instrument

An interesting backup-driven four-high rolling mill with coiling equipment built for the Allegheny Ludlum Steel Corporation was demonstrated in full operation at the stand of the Stanat Manufacturing Company, Long Island City, New York (Fig. 7). The machine has been developed to fill the need for a precise and rugged low-cost strip mill and is designed to handle both ferrous and non-ferrous strip at speeds up to 500ft per minute. The mill will roll down to less than 0·001in finishing gauge, holding a total thickness tolerance of 5 per cent. The "packaged" unit shown at the exhibition had 8in diameter by 10in face width backup rolls and uses work rolls within a 2½in to ¾in diameter range. The major innovation incorporated in this rolling mill is the backup drive method which is designed to facilitate (*a*) rapid work roll changing—a complete change requires only twenty minutes; (*b*) use of different diameter work rolls to suit the desired finishing thickness; (*c*) low cost and ruggedness of tungsten carbide work rolls due to simple shape; (*d*) heavy pass reductions without lateral "bowing out" of the work rolls; (*e*) heavy rolling torque capacity by virtue of extra-large universal spindles, and (*f*) easy convertibility to a two-high mill arrangement for break-down and skin-pass rolling.

The backup drive principle is proving a valuable asset to users of such mills. In the past, 4-high mill users were limited to only one size of work roll; now, the operator can select from a variety of rolls the one best suited to the job. Since these rolls are offered in sizes down to ¾in. diameter, the production of very thin gauge strip is facilitated. Moreover, the simple shape and short length of the work rolls is also of advantage in purchasing tungsten carbide work rolls: the simplicity of shape and compactness means a low initial cost, and the absence of driving

torques means freedom from torsional load failures. The mill is offered as a completely self-contained and fully wired "packaged" unit requiring no foundation work. Heavy cast steel housings, precision anti-friction roll neck bearings and individually or simultaneously operated screwdowns calibrated in 0·0001in, combine to facilitate strip being rolled to extra-close tolerances. The mill base is a reinforced steel plate weldment forming a 300-gallon reservoir for coolant storage. Individual roll coolant and bearing lubricant circulating, cooling and filtering systems are offered as optional equipment.

Depending on its application, the mill can be used as a non-reversing or reversing unit, with one or two individually motorised winding reels being employed. Variable speed drives available for the mill include variable voltage d.c., eddy-current clutch a.c. and gearshift a.c. systems. The mill motor is geared to the pinion stand which comprises herringbone gears and tapered roller bearings. The drive from the pinion stand to the backup rolls is through heavy-duty universal joint spindles having heavy torque transmitting capacities. The large alloy steel backup rolls of the mill become work rolls in the 2-high arrangement, thus allowing heavy bites to be taken in the hot or cold reduction of ingots and bars up to about 1½in thick. In place of flat rolls, grooved rolls can be fitted for the hot or cold processing of rounds, squares and other shapes. Optional mill equipment includes motorised screwdowns, pay-off and take-up reels, solid and collapsible winding blocks, tungsten carbide work rolls, continuous thickness gauges and backup roll internal cooling attachments.

An interesting exhibit in the field of ultrasonic machining of hard or brittle materials was the impact grinder displayed by the Raytheon Manufacturing Company, Waltham, Massachusetts. The operations performed by this unit include slicing, drilling, engraving, trepanning, shaping, and lapping. The installation comprises: (1) a driver unit which serves as a source of ultrasonic electrical power for the cutting head; (2) a pedestal unit that carries the cutting head and feeds the work to it; (3) an abrasive unit that circulates and feeds an abrasive fluid to the cutting tool; (4) a head unit that supports and drives the cutting tool; (5) an interconnection unit that provides electrical services and interconnections to the various units; and (6) a water flow switch unit to prevent operation without cooling water flow through the head unit. In principle, the Raytheon impact grinder employs an electro-mechanical transducer to convert alternating electrical current supplied by the driver unit into mechanical vibration at 25,000 c/s. The mechanical vibrations of the transducer are amplified and transmitted to the cutting tool by means of a shaped tool cone. The cutting tool is secured to the tip of the tool cone and vibrates perpendicularly to the tool face along the cone axis. A small space filled with abrasive fluid develops between the vibrating tool face and the workpiece. Tiny particles of abrasive are accelerated by the motion of the tool tip and are driven with tremendous impact against the work, thereby chipping or grinding an exact counterpart of the tool face into the work: hence the term "impact grinding." The work is fed up to the tool to maintain a constant grinding force between the two. Despite the fact that the abrasive particles strike the work with impact forces up to 150,000 times their own weight, the grinding force required seldom exceeds 10 lb. This small force, together with the vibrating nature of the process, the absence of direct tool-to-work contact and the presence of the cool abrasive, mean that impact grinding is a "cold-cutting" process. The work material is not stressed or distorted in any way, and is not raised in temperature. It is normally not necessary to clamp the work, and there is no tendency for the tool to wander. Existing or unfinished work may be taken up again with new or old tools without difficulty in re-centring.

As shown in the accompanying illustration, (Fig. 8), electrical current is supplied by the electronic driver unit to the excitation coil of the electro-mechanical transducer. This creates a magnetic field in the nickel stack which alternates at the same rate. Nickel is magnetostrictive and consequently the nickel stack expands and contracts 25,000 times per second with an amplitude of about 0·0004in. The transducer is held in space by a resonant support, which enables the vibrations to be transferred to the cutting tool without appreciable loss of energy and, at the same time, provides means for directing and controlling the cutting action. The rate at which material can be removed by impact grinding depends directly upon the amplitude of cutting tool vibration. High amplitudes provide high acceleration to the abrasive particles and ease the flow of new abrasive between the tool and the work. The cutting tool amplitudes vary from 0·004in with tools of small cutting face area to 0·0006in with tools of large cutting face area. Amplitudes smaller than 0·0006in require excessive machining time. The vibration amplitude of the nickel stack is amplified and transferred to the cutting tool by means of cones. A transmitting cone is a permanent part of the transducer and provides a fixed amount of amplification. Additional amplification is provided by the tool cone. The tool and cone system must resonate at or near the oscillatory frequency of the nickel stack, which can be tuned over a ±1500 c/s range by adjustment of the driver unit. The tool cones are detachable and must be selected for each particular grinding job. Some of the standard tool cones available for use with the grinder are cones with straight tapers, exponential tapers, and step tapers. The selection of the proper tool cone is usually straightforward, involving merely the selection of a cone having sufficient area at the tip for mounting the desired cutting tool.

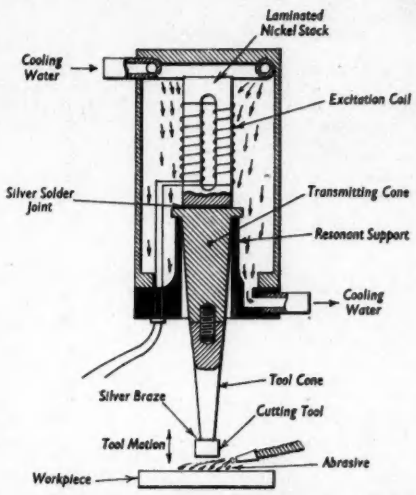


Fig. 8—Diagram of Raytheon ultrasonic "impact grinder" showing electro-mechanical transducer assembly

The Raytheon Manufacturing Company also exhibited its new "Weldpower" heat programme timer. It is an alternating-current resistance welding control unit which varies the weld heat in a pre-established sequence during the welding cycle to produce successful welds, previously considered impractical or impossible, between oxidised, greasy or otherwise coated metal surfaces. In addition, it is capable of welding highly conductive metals such as copper-to-copper, without resorting to a resistive metal insert or highly resistive electrode alloys. The timer is used in conjunction with a thyratron contactor unit to form a complete a.c. welding control. Combined with a welding transformer and a precision welding head, this versatile unit can perform rapid, high quality welds on a production basis without the need for preliminary cleaning or preparation of the surfaces to be joined. The timer may be used in any normal resistance welding application, but its greatest value lies in the fields where: (1) weld quality is important and optimum surface conditions cannot be maintained; (2) metals are known to be coated and cannot be cleaned for practical reasons; and (3) metals having high conductivity are to be joined.

In normal resistance welding, the high current densities suddenly impressed across relatively high resistance interfaces result in local heat concentrations sufficiently high to melt portions of the existing barrier film, which consequently shatters. The results are splashed weld particles on the surface of the material and weak welds due to energy loss. The principle of the heat programme timer is based upon the fact that, by a gradual increase in secondary welding current, the electrode-to-work interface can be properly "conditioned" before welding current magnitudes are reached. A gradual increase in secondary welding current is also utilised in welding highly conductive metals whose resistance at room temperature is too low to make the necessary heat. A gradual decrease in welding current after the weld is accomplished serves to anneal the welded area in those cases where undesirable embrittlement may occur. The timer, when combined with a thyratron contactor unit and a welding transformer, forms an installation capable of supplying welding current which varies according to a pre-established "programme" throughout three successive time intervals: (1) the conditioning period, or up slope time; (2) the welding period, or weld time, and (3) the annealing period, or down slope time. The magnitude of the welding current throughout each of these intervals can be controlled independently to meet the requirements imposed by the metals to be welded. During the up slope time, which is adjustable between two and ten cycles of the power line frequency, the welding current increases linearly from an initial, or low heat, value, to a final, or weld heat, value. During the weld time, which is independently adjustable from two to ten cycles, the welding current remains steady at the weld heat value. During the down slope time, also adjustable from two to ten cycles, the welding current decreases linearly to the low heat value again, then stops. All three time intervals, as well as the weld heat and low heat values, are adjustable by means of control knobs on the front panel of the timer.

(To be concluded)

Revision of the "Buy American" Act

THE American Administration is preparing a new formula which will give U.S. electrical equipment suppliers in areas of high unemployment a 15 per cent "edge" over foreign competitors, rather than the 6 per cent advantage now offered under the "Buy American" act. The "Buy American" act provides that competing low foreign bids to supply electrical equipment for federal installations can be raised to offset the advantage of cheaper overseas labour. Under the Democrats, this averaged about 25 per cent, while President Eisenhower reduced this to 6 to 10 per cent, which put British and European firms in a much more competitive position.

The new plan requires agreement among federal agencies on a percentage allowance and a method of determining what constitutes a labour surplus area. When the Bureau of Reclamation and the U.S. Army Corps of Engineers reach such an agreement, U.S. firms with works in such areas will be entitled to the percentage edge over foreign competitors. It is expected that the mark-up on foreign companies' bids will come to about 15 per cent. American companies in other areas where unemployment is not a problem will continue to receive the benefit of the 6 per cent mark-up on their competitors' bids.

Commercial Nuclear Development

THE General Electric Company, of Schenectady, New York, has taken options on a 1585-acre tract of land near San Francisco as a possible future site for a nuclear development facility. Plans for the use of the land will depend on studies now being made there of the specific requirements of such a development facility. The long-term purpose of this development facility would be in the application of atomic energy to a wide variety of peaceful uses. One of its important projects, initially, would be the support of work on a 180MW all-nuclear power station which the company will build for the Commonwealth Edison Company in the Chicago area.

Personal and Business

Appointments

MR. TERENCE O'NEILL has joined the Solartron Electronic Group, Ltd., as personal assistant to the commercial director.

TUBE INVESTMENTS, Ltd., states that Dr. T. P. Hughes has been appointed director of the research laboratories at Hinxton Hall, Cambridge.

MR. SAM BLACK has been appointed head of the publicity department of the British Electrical and Allied Manufacturers' Association, in place of the late Mr. J. J. Conlan.

R. B. PULLIN AND CO., Ltd., Brentford, Middlesex, states that Mr. R. K. Deane has been appointed production controller. Mr. H. R. Botting has been appointed chief buyer.

BRUSH ELECTRICAL ENGINEERING COMPANY, Ltd., Loughborough, states that Mr. R. Drinkwater has been appointed turbine specialist engineer in succession to Mr. R. D. Taylor, who is now the London branch manager.

TRIPLEX SAFETY GLASS COMPANY, Ltd., announces the appointment of Mr. K. J. B. Wolfe as head of fundamental research. He is to take charge of a new research department to be built at the company's Willesden factory.

MOBIL OIL COMPANY, Ltd., Caxton House, Westminster, S.W.1, announces the appointment of Mr. G. A. Dickins as manager of the technical department, in succession to Dr. R. B. Killingworth, who has now returned to the U.S.A.

SHEEPBRIDGE ALLOY CASTINGS, Ltd., announces the appointment of Mr. G. Brewer as cast iron bronze and foundry manager. Mr. D. Berridge has been appointed sales manager, Mr. E. G. Scrannage has become methods engineer, and Mr. S. Marton has been appointed to a new research position concerned with the continuous casting of bronze tubes.

THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH states that the resignation of Sir Edward Bullard, F.R.S., as director of the National Physical Laboratory takes effect at the end of this month. Pending the taking up of office by a new director, the Lord President of the Council has appointed Dr. R. L. Smith-Rose, M.I.E.E., to be acting director. Dr. Smith-Rose is director of radio research in the D.S.I.R.

THE DISTINGTON ENGINEERING COMPANY, Ltd. (branch of The United Steel Companies, Ltd.), states that Mr. A. E. Bell has been appointed general sales manager, and Mr. T. Wintrup has been appointed sales manager (engineering). Mr. T. S. Kilpatrick has relinquished his position as commercial manager in order to become deputy general manager of The Workington Iron and Steel Company. He will remain a director of The Distington Engineering Company, Ltd.

Business Announcements

SHEEPBRIDGE ENGINEERING, Ltd., has acquired the issued share capital of W. E. Bray and Co., Ltd., Feltham, Middlesex.

WINSTON ELECTRONICS, Ltd., Shepperton, Middlesex, states that its telegraphic address is to be changed on January 1st to "Winston, Shepperton."

J. H. FENNER AND CO., Ltd., Hull, has opened a new branch for mechanical power transmission equipment at 50, Southgate Street, Leicester.

A.C.V. SALES, Ltd., states that the Maudslay spares store is now situated at Castle Maudslay, Alcester, Warwickshire (telephone, Alcester 181, Ext. 24).

AUTO DIESELS, Ltd., Uxbridge, Middlesex, has announced that it will now adapt and supply "Standard" petrol, vaporising oil and diesel engines required for industrial purposes.

CHARLES COLSTON, Ltd., 3, Mill Street, London, W.1, states that it has acquired the assets of Tallent (Aycliffe), Ltd., Aycliffe, Co. Durham, and Smith-Richards, Ltd., High Wycombe, Bucks.

HAROLD ANDREWS SHEEPBRIDGE, Ltd., is the new title of the company formerly known as Harold Andrews Grinding Company, Ltd. Its address is unchanged at Manor Lane, Halesowen, Worcs.

WADKIN, Ltd., Leicester, states that it will acquire on January 2nd the whole of the issued share capital of J. Sagar and Co., Ltd., Canal Works, Halifax, and its three subsidiaries, namely, Sagar Bursgreen, Ltd., Burrows Green, Ltd., and Houghton Engineers, Ltd.

FAWCETT-FINNEY, Ltd., is the title of a sales and service company which has been formed jointly by Fawcett, Preston and Co., Ltd., Bromborough, and Finney Presses, Ltd., Birmingham. The head office and Midland sales office of the new company are at 27, Berkley Street, Birmingham, and there are branch offices at 60, Buckingham Palace Road, London, S.W.1, Bromborough, Cheshire, and at Mayfield Park South, Fishponds, Bristol.

Contracts

VICKERS-ARMSTRONGS (ENGINEERS), Ltd., has received a contract for extensions to the plant of The Chinnor Cement and Lime Company, Ltd. The contract covers new plant, including cement-making machinery, civil engineering, structural steelwork and electrical control gear, &c. The extension has been designed to increase the output at Chinnor by at least 100,000 tons a year.

VICKERS-ARMSTRONGS (AIRCRAFT), Ltd., is to supply to Continental Air Lines Inc., of Denver, U.S.A., twelve "Viscount" 810D airliners. Deliveries will begin in March, 1958, the aircraft each having four Rolls-Royce "Dart" R.Da.7/1 engines. Within twelve months it is intended to substitute R.Da.8 engines to raise the cruising speed from 363 to 400 m.p.h. The machines will carry fifty-two first-class passengers and have provision for two-crew operation, pressure refuelling and fuel jettisoning; cloud collision radar and built-in folding stairs will be fitted.

EDGAR ALLEN AND CO., Ltd., Sheffield, has signed a contract, valued at £750,000, with the Seven-Year-Plan Organisation of Iran, for the supply of cement-making machinery and equipment for the proposed Portland cement factory at Doroud, Iran. The plant will produce daily 600 tons of Portland cement. The equipment includes two rotary kilns, 330ft long by 9ft and 10ft 6in diameter, primary crusher, wash mills, tube mills for raw and finished materials, together with all ancillary equipment. The plant consists of two units, delivery of the first to be completed in eighteen months, and the second six months later.

Miscellanea

HEAVY-DUTY SOLDERING IRON.—A new soldering iron for very heavy duty, which is now being made by the Acru Electric Tool Manufacturing Company, Ltd., Chapel Street, Levenshulme, Manchester, 19, has a power consumption of 450W and is fitted with an element having an area of about 11 square inches. The iron weighs 8 lb and can be fitted with pointed, hatchet and chisel bits.

INTERNATIONAL CONFERENCE ON URBAN MOTORWAYS.—The British Road Federation has announced that an international conference will be held in London from September 17th to 20th 1956, to discuss urban motorways as a solution to traffic congestion. Invitations to this conference have been sent to thirty-five countries and to nearly 500 civic authorities in this country. Papers are to be presented by European and American experts, dealing with various aspects of urban motorway design and construction. A detailed programme of the conference is to issued early in the New Year.

SYNTHETIC RUBBER COATING.—An industrial coating based on synthetic rubber and known as "Semprene" has been introduced by Semtex, Ltd., Semtex House, London, N.W.9. It can be applied to iron, steel and aluminium surfaces that are free from paint, oxide film or other contamination. Four coats are brushed on or applied with a trowel at intervals of two hours, and, it is claimed, in a period of a few days the coat vulcanises at the prevailing temperature. "Semprene" is supplied in the form of a base coating and accelerator, and must be mixed within an hour of using. A gallon of base coating weighs about 12 lb and will give one coat to about 150 square feet of metal.

OIL FIRE FIGHTING.—The Mobil Oil Company, Ltd., recently showed a film in colour entitled "Beneath the Flames" which describes the control and extinguishing of oil tank fires by a new method, called "air agitation," which has been developed by the Socony Mobil Oil Co. Inc. of New York. The film shows the development of the air agitation method which is based on the principle that an inflammable liquid can burn only when the flames are fed by vapours rising from it mixed with oxygen in a burnable ratio. When this ratio is destroyed the fire dies or when the rate of mixing vapour and air is reduced there is a reduction in the flames and heat intensity. The chance discovery that a kerosine fire could be put out by the use of unheated kerosine led to research on the problem and this mounted from laboratory scale to a test fire in which a tank containing two million gallons of oil was ignited. Compressed air was passed into the bottom of the tank and by agitation of the contents the fire was extinguished in less than two minutes. The laboratory work and the subsequent large scale tests of the air agitation method are shown in the film which runs for twenty minutes. Copies may be obtained from the Information Section, Mobil Oil Company, Ltd., Caxton House, Tothill Street, Westminster, London, S.W.1.

KINGSWAY TUNNEL.—Last week, the Minister of Transport was asked in Parliament by Captain Kerby to consider using the Kingsway tramway tunnel as a motor road, to ease the flow of north-south traffic in the area and prevent it from holding up the east-west traffic flow along the Strand. In a written answer the Minister of Transport said that the matter had recently been examined by the London and Home Counties Traffic Advisory Committee. The committee's advice was that there could be no traffic use of the tunnel at the present time without prohibitive expenditure of funds which could be better used elsewhere on the roads. The committee would consider the matter again in 1957.

HYDRAULIC FORK LIFT TRUCKS.—The "KGA-51" series of industrial lift trucks manufactured by Yale and Towne, Ltd., at Philadelphia, Pennsylvania, have hydraulic actuation extended to gear selection. A hydraulic torque converter takes the power to an automatic gearbox in which the ratios are engaged by oil-operated, oil-cooled clutches. A single pump supplies converter and gearbox and circulates the oil through an auxiliary radiator. For refined manœuvring the transmission clutches can be slipped by slight pressure on the brake pedals provided for either foot; further depression applies the brakes hydraulically. This clutch control allows the engine to provide fast movement on the hydraulic lift motion, while the truck is being inched into position. The British Materials Handling Division of the company is at Wednesfield, Wolverhampton, Staffs.

CHROMIUM PLATING.—Chromium plating baths, as is generally known, contain rather concentrated solutions of chromic acid as well as small percentages of other chemicals, and a large volume of hydrogen is liberated during plating while oxygen is evolved at the anodes. These gases are produced in the form of bubbles, which burst violently at the surface of the concentrated acid solution, throwing out a fine mist, which is both corrosive and toxic. In general, an exhaust ventilation system is used continuously to remove the mist as it is formed, and the quantity of air exhausted for this purpose can be quite large. A new surface-active fluorinated hydrocarbon agent called "Zeromist" introduced by the Electro-Chemical Engineering Company, Ltd., of Weybridge, Surrey, is stated to create a thin safe foam blanket on a plating bath, which completely stops the evolution of chromium spray. The agent is supplied in the form of tablets and its use is stated not only to save the chromic acid, but also to reduce greatly the carry forward of chromium solution on the racks as well as almost completely eliminating the toxic and harmful chromium spray. It is claimed to be unaffected by the anode and cathode current densities normally used in decorative chromium plating.

DIESEL LOCOMOTIVES FOR EAST AFRICA.—Two new types of diesel locomotives suitable for shunting and trip working are being delivered to the East African Railways by the North British Locomotive Company. In many respects both of the locomotives are very similar although of different horsepowers. Under one order fourteen 300 h.p. 0-8-0 locomotives are being built, while the second order covers three 500 h.p. 0-8-0 diesel-hydraulic locomotives. The smaller locomotives each weigh 42 tons and are powered by Davey Paxman "8 RPH" normally aspirated diesel engines coupled through a cardan shaft to a Voith-North British torque converter hydraulic transmission. The larger locomotives weigh 52 tons and are powered by Davey Paxman "12 RPHX" supercharged engines coupled to the same form of transmission. The only other principal difference lies in the radiator arrangement, which in the case of the 300 h.p. locomotive has an axial flow of air, which is discharged at the top of the casing. In the case of the 500 h.p. locomotive the air is drawn in at the sides of the engine housing and expelled at the top of the casing. The hydraulic transmission is bolted to a final drive gearbox provided with jackshaft, which is arranged for two-speed gearing. This enables a locomotive to be used on shunting duties up to a maximum speed of 20 m.p.h. and on trip working duties up to a speed of 35 m.p.h. Timken tapered roller bearings, in addition to being fitted to the axlebox, have also been fitted to the side rods and crankpins.

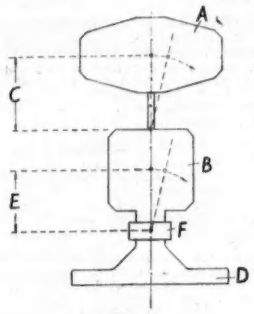
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicater are printed in italics. When an abridgement is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgement, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

POWER TRANSMISSION

738,601. January 27, 1953.—DAMPING SYSTEMS FOR ROTORS, Sandoz Ltd., 35, Lichtstrasse, Basle, Switzerland.

The invention relates to a method of damping rotating systems, such as self-centering centrifuge rotors and similar machines with vertical axes, normally operated above their critical speeds. In the drawing *A* is a rotor weighing approximately 3500 gm, coupled to a motor *B* by a flexible shaft having a free length of 50mm. The oscillation fre-



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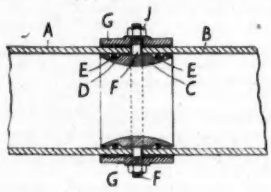
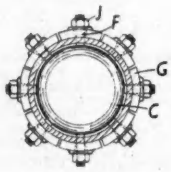
quency or natural frequency of the driven component consisting of the rotor *A* together with the flexible shaft is given principally by the mass of this component together with the distance *C* between the centre of mass of it and the base point of the flexible shaft, which is about 100mm. The resulting oscillation frequency or natural frequency n_1 has been found to be 170 per minute. The motor *B* which is connected with the base plate *D* by one or more elastic rubber supports weighs about 12,000gm. Its oscillation frequency or natural frequency, which is principally given by its mass and the distance *E* of about 140mm between the centre of its mass and of the supports *F* is increased and adjusted by its more or less strong connection with the base plate *D* as far as possible by a proper choice and fixing of the supports *F*. With the elastic supports described the oscillation or natural frequency n_2 of the motor *B* has been found to be about 400 per minute. The ratio between the two natural frequencies n_1/n_2 is then 17/40, thus fulfilling the conditions of the invention.—*October* 19, 1955.

TUBE AND PIPE COUPLINGS

738,934. October 12, 1953.—PIPE COUPLINGS, Lewis Mervyn Cecil Seamark, Pyne Cliff, Lyme Regis, Dorset.

The invention is of particular application to the coupling of pipes made of high-strength material having thin walls. In the construction illustrated in the drawing the two ends *A* and *B* of relatively thin-walled pipe of a high strength material are located and supported one on each side of a cylindrical member *C*. This member has on the outer surface





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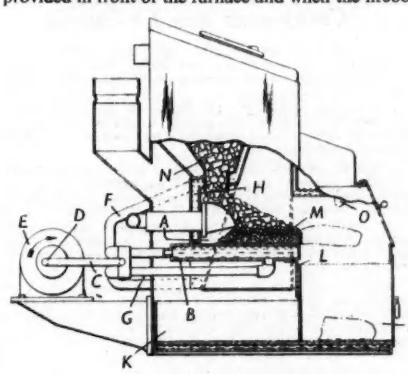
grooves *D* of shallow section at positions near the edges. In the groove are rings of resilient material *E* that normally project beyond the outer surface of the member *C*. The inner surface of the member *C* is curved as shown and it has formed integrally with it studs *F*, the ends of which are threaded. On the projecting ends of the studs are mounted centrally drilled clamping plates *G*, which have on the under surface teeth to engage the outer surfaces of the ends of the pipes. In operation the ends of the thin-walled pipes *A* and *B* are a loose fit around the cylinder *C*, the positions of the pipe ends being fixed by abutting against opposite sides of the studs. Clamping engagement of the pipe ends is effected by screwing down the nuts *J* on the studs. An effective liquid and watertight seal is secured by compression of the rubber rings *E* in the grooves *D*. Should the pressure inside the pipe be greater than the pressure outside, the rings will be forced into the outer corners of the grooves and towards the inner corners of the grooves in cases where the pressure outside the pipe is greater than the pressure inside the pipe. The coupling thus ensures against crushing of the pipe while ensuring an effective seal. While permitting expansion and contraction of the pipe a liquid and gastight seal is formed in both directions of application of pressure to the pipe.—*October* 19, 1955.

STEAM GENERATORS

737,565. March 19, 1952.—BOILER FURNACES, William Herbert Smith, The Cottage, Imber Court, East Molesey, Surrey.

The invention relates to boiler furnaces of the gravity feed type such as are used domestically for the production of hot water or steam, and provides automatic declinkering. As shown in the drawing, the base of the firebox *A* comprises a hollow rectangular water-filled chamber *B* mounted for sliding movement on guides at the sides. The base *B* is connected by a rod *C* to a crank *D* rotated through a gearbox by an electric motor *E*. Flexible water connections *F* and *G* are provided between inlet and outlet pipes of the hollow firebox base and the other water spaces *H* of the boiler. A clinker tray *J* is provided in front of the furnace and when the firebox



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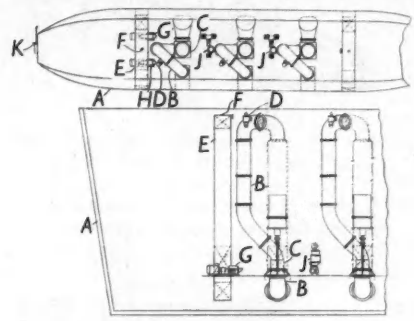
base *B* is moved forward it extends over the clinker tray. Beneath the firebox is a dust and ash tray *K* attached to the rear of the clinker tray and dust and ash fall from the firebox into this tray through narrow marginal passages *L* at the front of the base, and similar passages at the side of the base when the latter is reciprocated. When the base *B* is moved forward, it carries the clinker *M* forward, allowing fresh fuel to fall behind the clinker from a hopper *N* above the firebox. On the return movement only the base moves, the clinker *M* being prevented from moving back by the fresh fuel. The movement is repeated and the clinker is eventually ejected over the front edge of the firebox base. The clinker either breaks off due to its overhanging weight or may be broken off by a guillotine *O* in front of the firebox and operated in synchronism with the movement of the base. The guillotine may be driven from the moving base *B* or through gearing from the same motor. A modified construction is also shown in the specification.—*September* 28, 1955.

MARINE ENGINEERING

738,435. June 22, 1953, and July 27, 1953—PUMPING AND FILLING DRY DOCKS, Drysdale and Co., Ltd., and John Young, both of the company's address, Bon-Accord Works, Yoker, Glasgow.

The invention relates to a gate caisson construction for graving and like dry docks, in which the dock gate houses all the dock dewatering and filling equipment. In the drawing *A* is a dock gate, *B* the dock-emptying siphon pipes in which are intercalated axial flow pumps *C*. *D* is a breathing valve situated at the top of the invert of each siphon pipe *B* and *E* the dock filling siphon pipes at the top of the invert, of each of which there is provided a branch *F* connected to an air exhausting pump *G*. *H* is an air exhausting pump provided to prime the pumps *C*, while *J* are the pumps provided for dock drainage and bilge and ballast duties. *K* is the seating for the gate in the dock bottom and wall. In practice, to empty the dock the valves *D* at the inverts of the dock emptying pipes *B* are closed and the pumps *C* operated to fill the siphon pipes *B*. The water flows under the influence of the pumps and the siphonic action in the pipes from the interior of the dock to the exterior, the absence of valves in the installation producing a high efficiency of pumping in that friction losses are reduced to a minimum value. While the pumps *C* are discharging water from the dock a reaction is produced on the dock gate by the jets of water leaving the outlets of the siphon pipes *B*, this reaction causing the gate to be pressed against the seats *K* in the dock wall and bottom, thereby producing a degree of watertightness of the gate in the early stages of dewatering, when the static thrust of the water on the outside of the dock gate is a minimum. The jets of water from the outlets of the siphon pipe *B* are also effective in removing silt which may have gathered at the entrance to the dock. When the dock is empty



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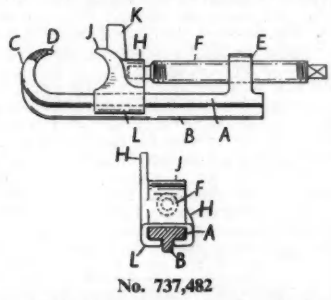
and it is desired to fill the dock the suction pumps *G* coupled to the filling siphon pipes *E* are operated. As the pressure within the filling siphon pipes drops, the water level rises inside the pipes *E* until the siphon pipes are filled, whereupon water starts to flow by siphonic action through the siphon pipes into the interior of the dock. The rate of filling of the dock may be increased by reversing the direction of the pumps *C* in the dock emptying siphon pipes *B*, water thereupon flowing through these siphon pipes in the reverse direction to increase the volume of water entering the dock in a given time. The siphonic filling action can be stopped at any time by admitting air to the inverts of the siphon pipes *E*. The use of a dock gate according to the invention simplifies the construction of the dock proper, since there is no need to provide the customary underwater level compartments for the dock pumping machinery, and culverts or valves for discharging and/or filling the dock.—*October* 12, 1955.

ROAD TRANSPORT

737,482. December 17, 1952.—SPRING STRETCHERS, Philemon Rees Gillard, of Hillside Garage, Danygraig Road, Melyn, Neath, Glamorgan.

The invention relates to spring stretchers for use in fitting multi-leaf road springs to vehicles, particularly transverse semi-elliptic leaf springs. As the drawing shows, the stretcher comprises a flat bar *A* formed on its underside with a longitudinal strengthening rib *B*. At one end the bar has an upstanding curved jaw *C*, shaped so as to fit around a spring



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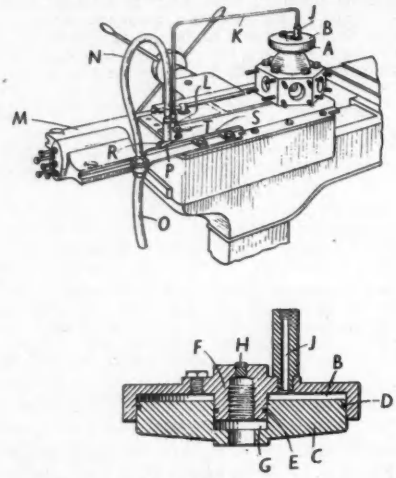
hanger or perch of a motor vehicle axle and cut away at its upper extremity as shown at *D* to embrace the stem of the hanger. At the other end the bar has a lug *E* having a threaded bore in which works a screwed shank *F*. The outer end of the shank is either squared as shown so as to fit a standard ratchet spanner or is provided with bores in which a tommy-bar can be inserted. At its inner end the shank *F* bears against a member *H* which is slidable on the bar *A* and which is formed with a jaw *J* shaped to engage the rolled end of a spring. The sliding member *H* carries an upstanding safety lug *K* and has a dovetail formation *L* which embraces the bar. In use, the spring is first attached at its mid-point to the vehicle chassis and at one end, through the usual shackle, to the spring hanger on one end of the axle. The hanger-engaging jaw *C* of the stretcher is then engaged with the spring hanger on the other end of the axle and the jaw *J* with the free end of the spring. By turning the shank *F* so as to screw the spring-engaging jaw *J* towards the hanger-engaging jaw *C*, the spring can be stretched until its end is close enough to the hanger for the second shackle to be fitted.—*September* 28, 1955.

MACHINE TOOLS

737,390. July 8, 1952.—TURRETS OF CAPSTAN LATHES, Austin Cartwright Mercer, 222, Rooley Lane Bradford.

The invention relates to turrets of capstan or turret lathes and concerns particularly the means for locking and unlocking the turret after and before its rotation into a fresh position. The drawing illustrates



No. 737,390

one construction of compressed-air-operated locking and unlocking means according to the invention. It consists of an actuating device *A* with a cylinder *B* in which a plunger *C* slides, there being sealing rings *E* and *D*, preferably of "O" section to give a fluid-tight fit. The cylinder has a central inwardly extending boss *F* over which fits a large bore *G* in the plunger *C*. The boss is internally threaded to receive the upper end of the usual non-rotatable turret screw or locking post of the turret locking device, a locking screw *H* being provided in the closed end of the boss for locking the cylinder on the post. The plunger can slide freely upon this turret screw or locking post and its lower face can be forced into contact with the turret body to lock it against rotation. The inlet and exhaust for the cylinder is provided by a single port *J* which is connected by a pipe *K* to a remote two-way control valve *L* mounted on the turret slide *M*. The two-way valve *L* has an outlet port connected to the cylinder by way of the pipe *K* and this port can communicate either with an inlet port connected by a flexible pipe *N* to the main compressed air line *O*, or with an exhaust port leading to atmosphere, according to the position of the valve piston. The valve *L* is actuated by valve-actuating mechanism, comprising a pivot arm *P* carrying a roller *R*, which, on the forward traverse of the turret slide, engages a cam face on a cam rail *S* fixed to the stationary part of the machine and opens the valve *L* to admit air to the cylinder and force the plunger down to lock the turret. On rearward traverse of the turret slide the arm *P* clears the rail *S* and drops, allowing the valve *L* to drop so as to close the inlet port and exhaust the cylinder to atmosphere. thus releasing the turret for indexing. A release tap *T* is provided on the body of the valve *L* to enable the cylinder *B* to be exhausted to unlock the turret when the turret slide *M* is in the forward position, with the arm *P* raised by rail *S*, for setting, adjusting or replacing tools or for like purposes. The invention has been described as operated by compressed air, but hydraulic fluid pressure could be used with a closed fluid circuit instead of exhausting to atmosphere.—*September* 28, 1955.

Launches and Trial Trips

NEVASA, troopship; built by Barclay, Curle and Co., Ltd., for the British India Steam Navigation Company, Ltd.; length 609ft, breadth 78ft, depth 57ft, gross tonnage 21,000; accommodation for service passengers 220 first-class, 100 second-class, 180 third-class and 69 sergeants and 931 troops; electric deck machinery, three 1200kW turbine-driven generators, one 450kW diesel-driven generator; two sets of double-reduction geared, triple-expansion turbines, steam supplied at 500 lb per square inch and 800 deg. Fah. by four water-tube boilers. Launch, November 30th.

CHARLES H. MERZ, collier; built by Hall Russell and Co., Ltd., for the Central Electricity Authority; length overall 340ft., length between perpendiculars 323ft, breadth moulded 43ft 3in, depth moulded 20ft 3in/25ft 9in, deadweight 3700 tons on 18ft draught; four holds, steam deck machinery; main machinery supplied by the North-Eastern Marine Engineering Co., Ltd., Sunderland, consists of one 14·5 i.h.p. direct-acting, triple-expansion steam engine, of "North Eastern Reheat" design, taking superheated steam at 220 lb per square inch from two oil-fired cylindrical boilers. Trial, November 30th.

DUKE OF LANCASTER, passenger and cargo ship; built at Belfast by Harland and Wolff, Ltd., for the British Transport Commission; length overall 375ft, length between perpendiculars 354ft, breadth moulded 55ft, depth moulded to main deck 19ft 6in, gross tonnage 5075 tons; 600 first-class passengers, including cabins for 240; 1200 third-class passengers, including cabins for 216; Denny-Brown stabilisers, two complete steel decks, eleven watertight compartments, two cargo holds forward; three 240kW diesel-driven generators and one 50kW diesel-driven emergency generator; two sets of double-reduction geared turbines; 10,500 total s.h.p., two Babcock and Wilcox boilers supply steam at 350 lb per square inch and 700 deg. Fah. Launch, December 1st.

NORTH MONARCH, oil tanker; built by the Blythswood Shipbuilding Company, Ltd., for the Compania Naviera Petrolera S.A., Panama; length between perpendiculars 610ft, breadth 82ft, depth moulded 44ft 6in, deadweight 27,500 tons; ten centre and twenty wing cargo oil compartments, one main cargo pump room, three 900 tons per hour turbine-driven horizontal centrifugal pumps and two 150 tons per hour stripping pumps; David Rowan and Co., Ltd., supplied the main machinery, consisting of one set of double-reduction geared turbines, 10,000 s.h.p. at 105 propeller r.p.m.; steam at 500 lb per square inch and 800 deg. Fah. provided by two oil-fired, forced draught Foster Wheeler pattern boilers. Launch, December 1st.

Catalogues and Brochures

W. C. HOLMES AND CO., Ltd. P.O. Box B7, Turnbridge, Huddersfield.—Illustrated catalogue dealing with "Schneible" multi-wash system for the collection and cleaning of dust-laden gases and fumes.

THE BENJAMIN ELECTRIC, Ltd., Brantwood Road, Tottenham, London, N.17.—Leaflet giving brief details of a dustproof fluorescent lighting fitting designed for totally-enclosed auxiliary gear and lampholders.

HENRY WIGGIN AND CO. Ltd., Wiggin Street, Birmingham, 16.—Detailed catalogue on Nimonic alloys, including design data and preliminary details of the recently introduced creep-resisting material Nimonic 100.

NEWALLS INSULATION CO., Ltd., Washington, County Durham.—Two illustrated catalogues dealing with combined heat and sound insulation on board ship, and cold insulating material for land and marine work.

SOCIETE NATIONALE DE CONSTRUCTIONS AERONAUTIQUES DU SUD-EST, 6, Avenue Marceau, Paris, VIIIe.—Brochure giving details of the Societe's factories and dealing with design facilities and general production. The main particulars are given for aircraft now in production, including several aircraft in series production.

NORTHERN ALUMINIUM COMPANY, Ltd., Banbury, Oxfordshire.—Booklet entitled "The Design and Construction of Welded Aluminium Deckhouses," outlining a method of constructing all-welded aluminium deckhouses and discussing the preparation of material, jigging, and including tables giving recommended welding procedures.

BRITISH PENS, Ltd., Bearwood Road, Birmingham.—Colour chart of the range of "Derwent" pencils which are made in seventy-two colours based on the official standards of the British Colour Council. These pencils are supplied separately or in sets for artists, designers, draughtsmen. &c., and in certain colours for metal marking purposes.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Jan. 4th.—MERSEYSIDE SECTION: Council Room, Chamber of Commerce, 1, Old Hall Street, Liverpool, 3, "Electronic Instrumentation for Nuclear Power," R. J. Cox, 7 p.m.

ILLUMINATING ENGINEERING SOCIETY

Wed., Jan. 4th.—NEWCASTLE CENTRE: Department of Electrical Engineering, King's College, College Road, Newcastle upon Tyne, "Airport Lighting," H. M. Ferguson, 6.15 p.m.——SWANSEA GROUP: S. Wales Electricity Board's Demonstration Theatre, The Kingsway, Swansea, "X-Rays in Medicine and Industry," K. Rawlings, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

Fri., Dec. 30th.—BIRMINGHAM BRANCH: Imperial Hotel, Birmingham, "Problems," 7.30 p.m.
Tues., Jan. 3rd.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, Debate, "That our main railroads be converted to highways," 7 p.m.
Wed., Jan. 4th.—SOUTHERN BRANCH: Polygon Hotel, Southampton, "Costing and Accountancy in Relation to Plant Engineering," S. J. Clark, 7.30 p.m.
Thurs., Jan. 5th.—PETERBOROUGH BRANCH: Campbell Hotel, Bridge Street, Peterborough, "Factory Flooring Problems," 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., Jan. 7th.—W. RIDING OF YORKSHIRE BRANCH: Technical College, Bradford, "The Use of Refractories in the Foundry," W. E. Ambler, 6.30 p.m.

INSTITUTE OF FUEL

Wed., Jan. 4th.—Institution of Civil Engineers, Great George Street, London, S.W.1, "Some Coal Research Problems and Their Industrial Implications," R. L. Brown, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Thurs., Dec. 29th.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Nuclear Power for Commercial Vessels," K. Maddocks, 7.30 p.m.

INSTITUTE OF PETROLEUM

Tues., Jan. 10th.—26, Portland Place, London, W.1, "Petroleum Fuels for Domestic Heating and Lighting," G. F. J. Murray and D. F. Tomkins, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Jan. 5th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Refrigeration Controls," H. H. Egginton, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Jan. 9th.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, "Gas Turbines and Their Application to Road Transport," A. Enticknap, 7.30 p.m.

INSTITUTE OF WELDING

Wed., Jan. 4th.—N. LONDON BRANCH: Manson House, Portland Place, London, W.1, "The Brittle Fracture of Mild Steel—A Survey," Constance F. Tipper, 7 p.m.—— MANCHESTER BRANCH: Reynolds Hall, College of Technology, Manchester, "Twenty Years of Welding Development," H. E. Lardge, 7.15 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Jan. 3rd.—MARITIME AND WATERWAYS MEETING: Great George Street, Westminster, London, S.W.1, "Reconstruction of the Gallions Entrance Lock at the Royal Docks of the Port of London Authority," J. A. Fisher, 5.30 p.m.
Tues., Jan. 10th.—RAILWAY MEETING: Great George Street, Westminster, London, S.W.1, "Consolidation of Ballast," I. G. White, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Jan. 2nd.—S. MIDLANDS CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Methods of Teaching Technical Writing," opened by G. Parr, 6 p.m.
Tues., Jan. 3rd.—N. MIDLANDS CENTRE: Central Electricity Authority, 1, Whitehall Road, Leeds, 1, "The Electrical Engineering Industry in the Post-War Economy II," G. L. E. Metz, 6.30 p.m.
Wed., Jan. 4th.—S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Automatic Circuit Reclosers," G. F. Peirson, A. H. Pollard and N. Care, 7 p.m.
Thurs., Jan. 5th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "Highland Water Power—The Developments of the North of Scotland Hydro-Electric Board," (the late T. Lawrie) paper to be read by an officer of the Board, 5.30 p.m.
Fri., Jan. 6th.—JOINT MEETING: Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Power Station Auxiliary Plant," G. F. Kennedy and F. J. Hutchinson, 5.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Thurs., Jan. 5th.—BIRMINGHAM AND DISTRICT BRANCH: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Mechanical Services in the B.E.A. Hangers at London Airport," L. Copeland Watts and J. W. J. Leslie, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Fri., Jan. 6th.— JOINT MEETING WITH THE INSTITUTION OF ELECTRICAL ENGINEERS: 1, Birdcage Walk, Westminster, London, S.W.1, "Power Station Auxiliary Plant," G. F. Kennedy and F. J. Hutchinson, 5.30 p.m.
Mon., Jan. 9th.—N.E. BRANCH: Stephenson Building, King's College, Newcastle upon Tyne, 2, Annual General Meeting, 6.15 p.m.
Tues., Jan. 10th.—AUTOMOBILE DIVISION: 1, Birdcage Walk, London, S.W.1, "Overdrives and Their Control," S. H. Ashby, 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., Jan. 3rd.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Power Plant for Telecommunications," W. J. Marshall, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., Jan. 3rd.—OXFORD SECTION: Town Hall, Oxford, "Cost Accounting as an Aid to Efficient Production," H. J. Furness, 7.15 p.m.
Wed., Jan. 4th.—WOLVERHAMPTON SECTION: Technical College, Wolverhampton, "Forgings and Pressings in High-Strength Aluminium Alloys," J. E. Earl, 7.15 p.m.——NOTTINGHAM SECTION: Victoria Station Hotel, Nottingham, Informal Discussion, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Wed., Jan. 4th.—LONDON GRADUATES' AND STUDENTS' SECTION: 11, Upper Belgrave Street, London, S.W.1, "Engineering in Europe and America," 6.30 p.m.——N. COUNTIES BRANCH: Neville Hall, Newcastle, Paper by D. W. Cooper, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Fri., Dec. 30th.—Pepys House, 14, Rochester Row, London, S.W.1, Question and Discussion Evening, 7 p.m.
Wed., Jan. 4th.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Josiah Wedgewood—The Potter," Miss R. J. Warne, 7 p.m.
Fri., Jan. 6th.—FILM EVENING: Pepys House, 14, Rochester Row, London, S.W.1, "T.L.B. Metal Powder Deposition Process," introduced by E. Wallace; and "Please Pass the Condensate," E. E. Bastick, 7 p.m.
Mon., Jan. 9th.—SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, Sheffield, "The Factory Act," D. E. Jones, 7.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Jan. 6th.—Engineers' Club, Albert Square, Manchester, "Polythene and its Uses," A. Renfrew, 6.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Jan. 3rd.—N.W. BRANCH: College of Technology, Sackville Street, Manchester, "Selection and Grading of Aggregates for Various Types of Concrete Works," J. D. McIntosh, 6.45 p.m.
Wed., Jan. 4th.—N.W. BRANCH: Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "Selection and Grading of Aggregates for Various Types of Concrete Works," J. D. McIntosh, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Jan. 5th.—YOUNG PEOPLE'S LECTURE: Institution of Civil Engineers, Great George Street, London, S.W.1, "Test Flying—Current Problems and Techniques," R. P. Beamont, 3 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Jan. 2nd.—ORDINARY GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "The Continuous Revision of Ordnance Survey Maps and Plans," A. H. Dowson and M. O. Collins, 5.30 p.m.